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APPLIED MECHANICS REVIEWS

VOL. 7, NO. 8 MARTIN GOLAND *Editor* AUGUST 1954

PROGRESS IN SUPERSONIC WIND-TUNNEL DESIGN

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PROGRESS in the aeronautical sciences relies to a large extent on experimental investigation either to check analytical results or to obtain data on problems too difficult to be investigated theoretically. The experimental techniques for supersonic aerodynamic investigation in the past few years have progressed in parallel with the development of supersonic aviation. New experimental methods have been developed in order to obtain more accurate, faster, and less expensive results.

The wind tunnel is a very useful tool for experimental aerodynamics. In recent years wind tunnels having different dimensions, range of Mach numbers, and basic design have been placed in operation in order to establish test conditions of interest to aeronautical scientists and to the designers in the aeronautical industry. Here we shall review some of the factors requiring these extended wind-tunnel designs.

AERODYNAMIC CHARACTERISTICS

The most important aerodynamic characteristic of a wind tunnel is the range of Mach numbers and the maximum Reynolds numbers to be realized in its test section. Because of the increased importance of viscous effects on the aerodynamic characteristics of bodies and because of the difficulty in extrapolating test results from one Reynolds number to another, it is currently considered desirable to simulate in wind tunnels Reynolds numbers corresponding to flight conditions. Unfortunately, the Reynolds number presently obtainable in supersonic tunnels is smaller than the Reynolds numbers corresponding to flight conditions.

Therefore, the trend in tunnel design is to increase the Reynolds number by two different means: The scale of the models tested is increased, requiring the wind tunnel's size to increase, and the static pressure in the test section is increased. Both means lead to an increase in the power required to operate the tunnel. For a given power, the Reynolds number is increased if the static pressure in the test section is increased and the dimension of the model is decreased. Therefore, the common tendency of today is in the direction of using, even in tunnels of large size, very high static pressures in the test section and thus large stagnation pressures. The upper limit to the value of the stagnation pressure which can be practically used is given by the practical possibility of building a model rigid enough for the high dynamic pressures and smooth enough for the Reynolds number of the tunnel.

CONTINUOUS WIND TUNNEL

Basically, wind tunnels are of two types: The continuous wind tunnel and the intermittent wind tunnel. The first type is usually a closed circuit tunnel unless gases are produced by the model, as, for example, in engine testing. Compressors or blowers are used as drivers; the air compressed by the blower is cooled and passed into a settling chamber, from which a nozzle expands and accelerates it to the test section. Finally, a diffuser recompresses and slows the gas before returning it to the blower.

The dimensions of continuous wind tunnels are steadily increasing as the models required for higher Reynolds number increase in size. Today supersonic wind tunnels of 10 $\times$ 10 or 16 $\times$ 16 ft are considered practical. The power installed in such tunnels is measured in units of 100,000 hp.

The choice of compressor characteristics which are flexible enough to permit a large range of test Mach numbers is a major design problem for continuous tunnels. Usually the tunnel has a fixed test section size and, therefore, the required compression ratio and the compressor capacity change with Mach number. The compression ratio varies from values on the order of 1.3–1.5 for Mach numbers close to one, to values on the order of 50 for Mach numbers on the order of 6.0. The volume flow required at the entrance of the compressor depends on the efficiency of the diffuser and, with efficient operation, decreases when the Mach number increases.

These characteristics of the tunnel usually do not match the characteristics of a single compressor and, therefore, several compressors of axial or centrifugal type are used in parallel for operation in the low Mach number range and in series in the high Mach number range. The necessity of using the compressors in different circuits makes the compressor installation complicated and extremely expensive.

Special care must be taken in the operation of a closed-system wind tunnel to eliminate dust and humidity from the air; both are introduced into the flow circuit during the installation of the model in the test section.

In tunnels of this continuous type, the nozzle is usually the two-dimensional, variable geometry type permitting tests to be carried out at various Mach numbers. The variation of the nozzle shape is obtained either by using extensive flexible walls or by a combination of rotation and translation of one or both nozzle blocks and with the deformation of the side wall shape confined

to a small region of the nozzle. The translation and rotation are used in order to reduce to a minimum the elastic deformation of the walls required for the range of Mach number desired.

The design of a variable Mach number nozzle presents a difficult engineering problem. The walls must be able to support large pressure differences, must remain cylindrical, and must be shaped with extreme precision. The sealing between the side walls and the flexible walls during the test presents also a difficult problem. The danger of overstressing the walls sometimes requires an elaborate and expensive control system which synchronizes the displacements of all the points along the nozzle. At the present time, quite different control systems for the flexible walls are in operation or in design; the differences are in part related to the minimum value of acceptable nonuniformity of the stream in the test section and to the divergence of opinion as to the convenience of automatic controls for the displacement of the flexible walls. The differences in complexity of the control systems are reflected in the cost of the tunnel.

INTERMITTENT WIND TUNNEL

The second type of wind tunnel, namely, that of the intermittent type, seems to offer very promising possibilities for future developments. This type at present is used only in small-sized wind tunnels, but offers large possibilities for large wind tunnels. At present, the actual running time of a continuous wind tunnel is a small fraction of the possible running time. A large amount of time is required for preparing models for tests, for installing, checking, and calibrating the instrumentation, for reaching the equilibrium conditions of the compressor system and of the humidity level, and for maintaining the rotating machinery. Furthermore, the required testing time itself can be substantially reduced, if necessary, by using fast-response, electronic instrumentation which at present is extensively developed. Strain-gage balances and electric manometers are used at the present time in continuous tunnels and are considered practical. Therefore, the running time required for a given series of measurements tends to decrease continuously and to become a very small fraction of the time required for the preparation of the tests. For these reasons, tunnels designed on the principle of storing energy over a considerable period of time in order to produce for a short duration a very powerful stream of air at high pressure and velocity seem logical.

Three different types of intermittent wind tunnels can be considered. A continuous wind tunnel can be transformed in an intermittent wind tunnel by using gas turbines, steam turbines, or hydraulic turbines, which use respectively air, steam, or water collected in a storage system, as drivers for the compressors in place of electric motors. The power installation requirements can thereby be reduced with respect to the conventional electric drive because the energy used for each run can be produced in the length of time between runs. This type of tunnel, however, would require compressors and turbines and, therefore, the reduction of construction cost would be small.

Two other types of intermittent tunnels can be considered. A supersonic tunnel can be driven for a short duration by connecting the tunnel discharge with a vacuum storage system, or by connecting the settling chamber with a storage system of pressurized air. The first scheme uses atmosphere stagnation pressures, and therefore, is less practical; it requires very large test sections for a given Reynolds number and, therefore, extremely large models. The second scheme is more promising because of the possibility of obtaining very high Reynolds number by increasing the value of the stagnation pressure.

In this second type of intermittent tunnel, the equipment consists of an air supply having a compressor usually of the reciprocating type and of small power, a small high-pressure drier, and a storage system. The maximum storage pressure used is high and varies from 40 to 300 atm in the existing equipment of this type. The air is discharged from the storage system across a pressure regulator, which keeps the pressure downstream of the pressure regulator constant. Because of the expansion of the air in the storage system, the temperature upstream of the pressure regulator is not constant. However, the Joule-Thomson effect across the pressure regulator tends to decrease the variation with time of the temperature downstream of the pressure regulator. Nevertheless, for short duration runs involving high rates of mass flow, a temperature stabilizer is required downstream of the pressure regulator. The simplest temperature stabilizer is of the inertia type and consists of a container filled with material such as metallic spheres or tubes and having large contact surface and large heat capacity. The stabilizer can be used also as the honeycomb or flow straightener for the settling chamber.

The nozzle design for intermittent tunnels is similar to the design used in continuous tunnels, while the diffuser is much simpler. The value of the stagnation pressure used is high in order to obtain high Reynolds numbers, and therefore high pressure ratios are available. Under these circumstances, the pressure recovery of the diffuser is not important. In the lower range of Mach numbers, the value of the stagnation pressure is usually high enough to eliminate altogether the necessity of a diffuser. The noise level of the discharge stream is a serious problem for this type of installation since large amounts of energy are dissipated in noise. Silencers must be installed if the facility is located in a populated region.

This type of tunnel is more flexible as to Mach number range than the continuous tunnel because of the possibility of varying mass flow and pressure ratio in a simple manner. Moreover, it requires power installations on the order of a few thousand kilowatts even for tunnels for very large dimensions, if the running time is limited to the minimum required for actually making the required measurements.

TECHNICAL PROBLEMS

Several technical problems are still not completely solved in supersonic wind-tunnel techniques; some of these are:

1 The effect of free-stream turbulence on the aerodynamic quantities measured, and the relation between turbulence or noise level of the stream in the settling chamber on the fluctuations of the flow properties in the test section.

2 The effect of roughness of the model surfaces on the boundary-layer transition.

3 The effect of nonuniformity of stream on the aerodynamic qualities measured.

The first effect is important because in supersonic tunnels the turbulence can be produced by temperature, pressure, and velocity fluctuations and by the noise level of the equipment, which is normally high. It is known that free-stream turbulence affects boundary-layer transition. The problem of roughness is an important parameter to be considered in the choice of the operating level of the static pressure. The effect of the roughness on the aerodynamic results is related to the boundary-layer thickness and therefore can become very important when small models are used and when high Reynolds numbers are obtained by using high stagnation pressures. Under these circumstances, boundary-layer thickness becomes very small and the roughness can become a primary parameter.

The effect of nonuniformity of the stream on experimental results is also a parameter not well defined. Presently it is generally accepted that the velocity distribution in the test section must be as uniform as possible. Several improvements in the aerodynamic

design of nozzles to permit this uniformity to be realized have been introduced. However, large differences of opinion exist on the minimum value of uniformity necessary in order to obtain reliable experimental data. Large amounts of work and complicated facilities are required in order to obtain a stream of high uniformity for a range of Reynolds number and Mach number. Therefore, often small fluctuations in the velocity vector with respect to an average value are accepted.

Another problem which is being encountered as the range of Mach numbers to be reached by supersonic wind tunnels is increased is that connected with high stagnation temperatures. When the Mach number in the test section increases, the expansion in the nozzle increases also, and the static temperature in the test section decreases. Therefore, for high enough Mach numbers the stagnation temperature of the air must be raised with respect to atmospheric conditions in order to avoid condensation of the components of air in the test section. The necessity of installing heating systems in the circuit of a hypersonic tunnel complicates further the design and cost of the tunnel, but is necessary if high Mach numbers are to be realized.

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Theoretical and Experimental Methods

(See also Revs. 2380, 2382, 2388, 2390, 2394, 2423, 2439, 2442, 2476, 2520, 2592, 2608)

2365. Salvadori, M. G., and Schwarz, R. J., Differential equations in engineering problems, New York, Prentice-Hall, Inc., xiv + 432 pp. $6.50.

Authors are to be congratulated for this valuable addition to the few excellent books in which mathematics is presented from the engineer's point of view. This means that the physical aspects of the problems are emphasized, once a solid mathematical foundation is given. Reviewer is sure that this book will serve for students who are learning how to set up and solve differential equations, as well as for engineers when solving actual problems in their respective fields.

The book consists of eleven chapters. The first chapter, the introduction, reviews some background material including basic principles of mechanics, thermodynamics, and electricity. The second chapter presents the setting up of ordinary differential equations for problems which occur in various engineering fields. The solution of homogeneous linear differential equations with constant coefficients is treated in the third chapter, and that of the nonhomogeneous linear differential equations in the fourth chapter. Laplace transforms and initial value problems are discussed in the fifth chapter. The sixth chapter treats the solution of simultaneous linear differential equations, and the seventh presents integration by series. The next four chapters deal with Bessel functions, nonlinear differential equations and elliptic integrals, solution of differential equations by Fourier series, and partial differential equations. A great number of problems are given (most of them with answers) at the end of each chapter. The book is well organized and neatly executed.

T. P. Torda, USA

2366. Southwell, R. V., and Vaisey, G., On some eigenvalue problems of exceptional difficulty, exemplified by a case of elastic instability, *Quart. J. Mech. appl. Math.* **6,** 4, 453–480, Dec. 1953.

For elastic instability of flat plates it is possible that (1) the gravest mode may be characterized by nodal lines and, as such, be impossible to guess with accuracy; (2) eigenvalues may be both positive and negative; (3) two or more of the gravest eigenvalues may be nearly or exactly equal.

These possibilities imply that a solution obtained by numerical means may, unwittingly, not be the desired one, namely, the lowest eigenvalue or gravest mode.

Authors devise means whereby these difficulties are surmounted, and allow the relaxation technique to be applied with assurance of obtaining the desired solution. One device mentioned, called "optimal synthesis," is already in use and was reported earlier by the senior author. A new device is that of "exploration" with a point load applied normal to plate surface. Technique is here applied to a problem reported in 1941. Although not suspected then, (1), (2), and (3) characterize that example; for all practical purposes, all three difficulties are surmounted in present paper.

F. S. Shaw, Australia

2367. Zachrisson, L. E., The one-point boundary problem of some variation equations (French and English), *Publ. sci. tech. Min. Air, Paris* no. 281, 31–43, 1953.

2368. Makinson, R. E. B., and Turner, J. S., On perturbation and variation methods, *Proc. phys. Soc. Lond.* **66,** 406 A, part 10, 857–865, Oct. 1953.

These two methods of approximating to the solutions of a second-order differential equation in one variable are shown to be essentially identical when expressed in terms of the theory of functionals. The application is made here to Schrödinger's radial wave equation, for both bound and unbound states. Methods are given for finding expressions which are stationary to the second order, and the essentials of the theory of functionals are sketched in an appendix.

H. C. Corben, USA

2369. Harrop, R., An introduction to the method of characteristics, *Aircr. Engng.* **25,** 295, 277–285, Sept. 1953.

2370. Gantmakher, F. R., Theory of matrixes [**Teoriya matrits**], Moscow, Gosud. Izdat. Tekh.-Teor. Lit., 1953, 491 pp.

This comprehensive volume originates in the author's lectures at Russian universities and technical high schools. There is not, in reviewer's opinion, another work in the world literature showing so completely the theory and applications of matrix calculus, which is becoming more and more significant in mechanics, electrotechnics, and theoretical physics.

Book contains two main parts. The first is divided into 10 chapters devoted, for the most part, to theoretical considerations. The second contains more advanced problems and applications of the theory. Nevertheless, even in the first part, many questions are considered which are important in engineering science: Mechanical significance of the well-known Gauss algorithm in the theory of sets of linear algebraic equations (2nd chapter); integration of systems of linear differential equations with constant coefficients by means of functions of matrixes (5th chapter); stability of motion in the case of a linear system (5th chapter); and, finally, small oscillations of a system with n degrees of freedom (10th chapter).

In the second part, the engineer's attention is called especially to chapter 14, treating systematically the use of matrixes in the study of systems of linear differential equations, and to chapter 15, having for its subject the famous problem of Routh-Hurwitz.

Presentation is clear and vivid; print is excellent. The book must be recommended as one of the most successful works of this kind.

V. Vodička, Czechoslovakia

2371. Truesdell, C., The physical components of vectors and tensors, *ZAMM* **33,** 10/11, 345–356, Oct./Nov. 1953.

Physical components of vectors and tensors referred to general curvilinear coordinates are defined and shown to represent quantities possessed of the natural physical dimensions of the field and capable of immediate physical interpretation. It is shown that scalar functions of second-order tensors may be expressed directly in terms of the invariants of the physical components. For the case of orthogonal coordinates, a general formula for the physical components of the covariant derivative of a tensor of any order is derived.

From author's summary by J. Lense, Germany

✎2372. **Nevanlinna, R., Single-valued analytic functions [Eindeutige analytische funktionen], 2nd rev. ed. (Grundlehren der mathematischen Wissenschaften, Bd. 46),** Berlin, Springer-Verlag, 1953, x + 379 pp., 24 figs. DM 46.50.

This is a second edition of the now classic book by Professor Nevanlinna on single-valued analytic functions. The main purpose of this edition has been to give some new results which have been obtained by his students in the past few years and, in some places, to simplify the existing proofs of known results.

The main new results concern the "principle of the counting functions" (Prinzip der Anzahlfunktionen), which has been developed by O. Lehto, and a simplified proof of what is called the second fundamental theorem of the theory of the distribution of values (Wertverteilungs-theorie), due to K. I. Virtanen. This is also referred to as the second fundamental theorem of the theory of meromorphic functions.

New results are also given on the theory of sets of capacity zero, and the section on quasi-conformal mapping has been edited again and made more complete. A new proof is also given of the distortion theorem of L. Ahlfors.

Aside from these and a few more minor changes, this edition remains the same as the old edition. The following table of contents will give the uninitiated an idea of the topics covered: 1. Conformal mapping of simply and multiply connected domains. 2. Solution of the Dirichlet problem for a simple domain. 3. Function theoretical majorant principles. 4. Relations between non-Euclidean and Euclidean measures. 5. Point sets of zero harmonic measure. 6. First fundamental theorem of meromorphic functions. 7. Functions of bounded type. 8. Meromorphic functions of finite order. 9. The second fundamental theorem of the theory of meromorphic functions. 10. Application of the second fundamental theorem. 11. The Riemann surface of a single-valued function. 12. The type of a Riemann surface. 13. The Ahlfors theory of the covering surfaces.

A. Devinatz, USA

✎2373. **Table of natural logarithms for arguments between zero and five to sixteen decimal places,** U. S. Dept. Comm., Nat. Bur. Stands., *Appl. Math. Ser.* no. 31, 501 pp. $3.25.

This is a revision of MT 10, volume 3. Only the introduction has been changed. The interval of tabulation is 0.0001. Table is definitive and an error is yet to be uncovered.

Y. Luke, USA

2374. **Rowe, A. J., The work-sampling technique,** *Trans. ASME* **76,** 2, 331–335, Feb. 1954.

Paper describes application of sampling theory to problem of finding machine down time. Use of random numbers for setting observation times is illustrated. Formula for required number of observations for various degrees of accuracy is given and a short table of values is exhibited. Use of chi-square test and quality-control chart techniques to check validity of underlying assumptions is described. All theory given can be found in the nine references. This is a summary and organization paper which fails to outline all of the pitfalls of actual use of the technique; for example, the definition of accuracy is obscure and the random method of observation time determination omits an important working period of 11 to 1 o'clock. Reviewer feels value of paper lies in its presentation of sampling theory to Methods Department personnel, although numerical results of the example are not given and apparent sampling period is too short.

E. C. Varnum, USA

2375. **Brisby, M. D. J., The application of statistics to engineering problems,** *Engineering* **174,** 4519, 294–296, Sept. 1952.

Examples are given of engineering problems solved by statistically analyzing data from administrative and accounting records.

Congestion in works railway systems is analyzed by graphs of "terminal user time" and standage charges and also by frequency diagram of period of wagon staying. Use of bell-shaped histogram is illustrated by control of length of rolled rails and that of wagon loading. Exponential distribution is fitted to histogram of time intervals between train arrivals to explain peak-load problems.

Reviewer believes this is a good exposition of some aspects of Operations Research [AMR **7,** pp. 89–93].

S. Moriguti, Japan

2376. **Liebmann, G., and Bailey, R., An improved experimental iteration method for use with resistance-network analogues,** *Brit. J. appl. Phys.* **5,** 1, 32–35, Jan. 1954.

When solving the wave equation $\nabla^2 U + k^2 U = 0$, and similar field problems, on resistance-network analogs by iteration, an error signal can be derived which is a measure of how far the analog solution satisfied the given equation. An experimental apparatus is described for displaying simultaneously, on a cathode-ray tube screen, the error signals ϵ for a number of resistance-network points; the solution then proceeds until all $\epsilon \simeq 0$. The apparatus can also be used to display network voltages or gradients, which is helpful in many other kinds of problems solved with resistance-network analogs, and to obtain solutions of "best fit" in equation solvers.

From authors' summary

2377. **Chu, Y., and Yeh, V. C. M., Study of cubic characteristic equation by root-locus method,** *Trans. ASME* **76,** 3, 343–348, Apr. 1954.

Paper shows that all possible roots of a cubic characteristic equation lie on a portion of a hyperbola and of its axis. This hyperbola may be sketched readily from the values of the coefficients of the cubic equation. Hence the change of the roots of the cubic equation due to any change in its coefficients may be visualized. The discussion of the transient response in relation to possible root configurations is included. A root-locus chart is provided for "universal" use. Results from an analog computer are shown to agree with those in this paper.

From authors' summary

2378. **Bereis, R., Drawing method for cycloids** (in German), *Öst. Ing.-Arch.* **7,** 4, 328–331, 1953.

A simple procedure for drawing cycloids and pseudocycloids is described. A. R. Mitchell, Scotland

2379. **Bilimovitch, A., On the dimensional homogenization of equations of hodographic type** (in French), *Acad. Serbe Sci. Publ. math.* **5,** 29–34, 1953.

Mechanics (Dynamics, Statics, Kinematics)

(See also Rev. 2696)

✎2380. **Yokota, S., Scientific and technical papers** (in English and Japanese), compiled and published by The Yokota Memorial Committee, Univ. of Tokyo, 1954, xx + 535 pp.

This memorial volume contains reprints of the scientific and technical papers of Seinen Yokota, the late Professor Emeritus of the University of Tokyo. 46 papers are included, amply demonstrating the wide versatility and excellent research contributions of the author. Two additional papers, which bear closely on Professor Yokota's work, are included in the appendix. The papers cover the general fields of numerical analysis, mechanics, elasticity, vibration, and fluid flow. Ed.

2381. Thumim, C., Constant torque power cams, *Prod. Engng.* **25, 2, 180–186, Feb. 1954.**

Paper describes procedure for designing power cams—as distinguished from time-displacement cams. Numerical examples are included and the analysis is extended to include friction.

From author's summary

2382. Freudenstein, F., An analytical approach to the design of four-link mechanisms, *Trans. ASME* **76, 3, 483–489, Apr. 1954.**

The new approach to the problem of the four-link mechanism is based on symmetry conditions of the four-link mechanism considered as a vector diagram. Thus, if a, b, c, d are the members of the four-link mechanism, then $a + b + c + d = 0$ is the vector equation which remains unchanged when the letter symbols a, b, c, d are cyclically interchanged. The equivalent algebraic expression is investigated, as are certain parameters P which likewise do not change with a cyclic interchange of the letter symbols.

The idea of cyclic interchange of symbols to be considered as an operation is then introduced and a suitable operator L for the function $H(a, b, c, d, P)$ set up. The choice of the symbol L for this operator is unfortunate, because it may create confusion with symbol L for the Laplace operator. Nevertheless, the introduction of this operator brings about a considerable simplification as it allows the setting up of a functional equation for H, which latter is now designated by x. The internal angles of the four-link mechanism can then be determined as functions of x and the first cyclic interchange x'. The resulting equation is solved by a method adapted from an example by Babbage for a symmetrical function. The general solution leads to an equation $C_1x^5 + C_2x^4 + C_3x^3 + C_4x^2 + C_5x + C_6 = 0$, which can be reduced to a second-degree equation by a proper choice of the coefficients in terms of two arbitrary functions M and N in a, b, c, d, P, and their first cyclic interchanges.

Next, it is shown how the parameter P may be chosen and how it can be interpreted as a length that may easily be found from the original four-link mechanism by drawing to any two adjacent sides parallels and joining the vertex of this parallelogram not belonging to the linkage to the vertex of the linkage not belonging to the parallelogram. This length is the parameter P.

Four auxiliary angles at the ends of the parameter are introduced and are used for determining the internal angles of the four-link mechanism, that is, the angular displacements, velocity, and acceleration ratios, as well as the motion of any point in the plane of the connecting rod, for constant angular velocity. The angular velocity of the connecting rod is also determined.

Formulas for the variation of the auxiliary angles with P for pure and mixed limits, which are explained, are established. Angular displacements in linkages obtained from a given linkage by permutation of the links are tabulated. Applications with examples are presented and formulas for various linkage mechanisms are given in tabular form. Problems which are suited to this form of analysis are discussed. It is shown how graphical techniques may be developed. A brief bibliography is appended.

A. E. R. de Jonge, USA

2383. Tosatto, G., Crosshead kinematics (in Italian), *Assn. Tecn. Auto.* **5, 12, 601–608, Dec. 1952.**

Paper deals with graphical determination of speed and acceleration of single points in crossheads according to the method of Rosebrugh of Toronto. Author correlates these points with points in a rotating rigid body, calling them "phorographs." Method of obtaining the phorographs for any point is given. The determination of acceleration is possible when the Coriolis component is zero and when the absolute acceleration in a point of the crosshead is known. L. Villena, Spain

Servomechanisms, Governors, Gyroscopics

2384. Iberall, A. S., Static-flow characteristics of single and two-stage spring-loaded gas pressure regulators, *Trans. ASME* **76, 3, 363–373, Apr. 1954.**

Detailed analysis is given of the effects of supply pressure and flow changes on the ideal regulated pressure. Author develops expression for regulated pressure which includes correction terms for both the above effects separately and a term taking account of kinetic energy in the incoming stream. Consideration is given to small metering valve displacements when the flow is governed by the orifice between valve and valve seat rather than the metering orifice proper.

Governing equations of the regulator are expressed in dimensionless form, suitable for graphical representation. Detailed explanation is given of the construction of a set of regulator characteristics both for regulators in which the pressure acts to close and to open the metering valve. These consist of lines of constant supply pressure, the coordinates representing regulated pressure and flow. The area is divided by a "no-regulation" boundary, the lower part being governed by the fixed metering orifice when the valve is well open.

The work is repeated for a two-stage regulator, and the resulting improvement in regulation compared with a single stage is shown. Finally, the analysis is applied to a range of similar commercial regulators, and close agreement with test results is evident.

Reviewer believes that the graphical interpretation of the theory will facilitate the original design of gas regulators to fulfill specific requirements and will lead to prototypes requiring little modification during their development. E. Giffen, England

2385. Gabbay, E. J., Theoretical formulation of cabin temperature control, *Aircr. Engng.* **26, 301, 64–69, Mar. 1954.**

Paper gives a simplified theoretical approach to the problem of temperature control of an aircraft cabin. Ideal controller is shown to require proportional, derivative, and integrating components. Author indicates how these components may be approximated in practice by modifications of a Wheatstone bridge. Development of transfer functions for various elements in control loop is fully illustrated and should prove of interest to a newcomer in this field.

In the reviewer's opinion, the paper gives a clear exposition of method of deriving transfer functions from physical considerations. However. there appears to be nothing new in the methods or approach. W. A. Wolfe, Canada

2386. Shearer, J. L., Dynamic characteristics of valve-controlled hydraulic servomotors, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-147, 23 pp.

Paper is a theoretical analysis of the dynamics of a 4-way valve and cylinder. This problem was previously considered on a theoretical basis in discussion by S. Z. Dushkes published with paper by Gold, Otto, Ransom [*Trans. ASME* **75, 7**, 1392–1393, Oct. 1953]. In that discussion, transfer function as derived contained single integration with first-order lag term. Parameters appearing in time constant were load mass, cylinder area, and partial derivative of load flow with respect to load pressure drop. Author in his analysis considers also compressibility of fluid, elasticity of fluid lines, viscous damping of load, and cylinder leakage. Transfer function as derived by author contains single integration with second-order lag term. Transfer function of author can be shown to reduce to transfer function in above-mentioned discussion if additional parameters considered by author are assumed to be sufficiently small to be disregarded.

Paper is a welcome addition to a growing body of literature on the dynamics of hydraulic servomechanisms and components and is recommended to anyone in the servo field. Good bibliography is included. S. Z. Dushkes, USA

2387. **Shearer, J. L., Proportional control of rate-type servomotors,** ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-146, 12 pp.

Simple second- and third-order control systems containing rate-type servomotors are discussed. Results of some studies of third-order system by analog computer are presented in graphical form.

Last sentence of discussion under "Characteristics of rate-type servomotors" erroneously implies that a control system represented by second-order differential equation with positive coefficients may be unstable if "inertia" and "spring" terms are sufficiently large. L. Becker, USA

2388. **Piatt, A., Mechanical analog-computing elements and their applications to automatic control,** ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-141, 10 pp.

Paper opens with some elementary remarks about open-loop and closed-loop computers. This is followed by brief discussions of some purely mechanical computing components, namely, the differential gear, summing levers, multiplying linkages, ball-and-dish integrators, and function-generating linkages.

The application of these devices to two industrial control problems is given by way of illustrating elementary principles. These examples are a computing and integrating flowmeter and a control for a heat-transfer process.

Since this paper was intended only to point out the utility and importance of analog computers of the mechanical type to industrial control processes, no extensive treatment of the basic theories involved is included. H. M. Trent, USA

2389. **Westover, T. A., Dynamic performance evaluation of feedback control systems,** ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-129, 8 pp.

Methods are discussed for determining the dynamic performance of feedback control systems or servomechanisms. Test equipment arranged and packaged as one convenient instrument is described. From author's summary

2390. **Mitrovic, D., On a nonlinear servomechanism of several independent variables** (in French), *C. R. Acad. Sci. Paris* **237**, 20, 1209–1211, Nov. 1953.

An analog computer is described for solving nonlinear systems $y'' = f(t, y, y')$. The initial conditions $y(0)$ and $y'(0)$ at the time $t = 0$ are formed by use of two coupled feedback circuits which pick up the conditions $y(t_1)$ and $y'(t_1)$ at the time t_1.
W. Oppelt, Germany

2391. **Briggs, B. R., and Jones, A. L., Techniques for calculating parameters of nonlinear dynamic systems from response data,** *NACA TN* 2977, 67 pp., July 1953.

The derivation of system parameters from experimental response data is a problem often encountered in dynamic testing. The authors have used the experience obtained in reducing flight and wind-tunnel dynamic test data to extend previously developed techniques for analyzing linear systems to certain simple types of nonlinear systems. Satisfactory results can be obtained if the analyst is able to intuitively determine the order and form of the differential equation representing the system under consideration. W. F. Milliken, Jr., USA

2392. **Frenkel, M. S., A new speed responsive device for governors,** *Engng. Boiler House Rev.* **66**, 10, 294–300, Oct. 1951.

The article presents the theory of a ball-and-cup-type governor which is sensitive to mean shaft speed but insensitive to small fluctuations in shaft speed. By properly proportioning the parts, friction is made to prevent relative motion of the primary parts unless shaft acceleration is above a pre-established magnitude. Thus no wear occurs as a result of small speed fluctuations. For large accelerations, the motion is such that the total friction forces are nearly perpendicular to the direction of controlling motion, so the effect of internal friction is minimized. Therefore the governor is said to be very sensitive to changes in mean shaft speed.

Mathematical derivation of the theory is presented in part.
S. Zivi, USA

Vibrations, Balancing

(See also Revs. 2380, 2406, 2407, 2669, 2670)

2393. **Davenport, W. W., and Kruszewski, E. T., A substitute-stringer approach for including shear-lag effects in box-beam vibrations,** *NACA TN* 3158, 23 pp., Jan. 1954.

Vibration characteristics of simple thin-walled hollow rectangular beams of uniform wall thickness are compared with vibration characteristics of a substitute stringer structure which is to have the same shear-lag properties. The effect of location of four stringers from four corner flanges on vibration frequency is studied for various cross-sectional and planform aspect ratios. This location can be so chosen that the first three symmetric beam-wise bending frequencies agree very closely with the exact solutions. No attempt is made at generalization to more typical structures. E. T. Welmers, USA

2394. **Bogdanoff, J. L., Goldberg, J. E., and Lo, H., Application of Volterra linear integral equations to the numerical solution of beam vibration problems,** Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 81–88, Apr. 1953.

The formulation of the beam-vibration boundary-value problem in terms of a Volterra integral equation of the second kind provides the basis for an approximate numerical method of finding natural frequencies and principle modes. Although the advantage of the method lies in the ease of application to nonuniform beams, authors present numerical results for four problems dealing with vibration of a uniform cantilever beam. Comparison with exact results in two of the problems indicates excellent accuracy, both in regard to frequency and mode shape.
P. G. Jones, USA

2395. **Jones, R. P. N., The wave method for solving flexural vibration problems,** *J. appl. Mech.* **21**, 1, 75–80, Mar. 1954.

Author is primarily concerned with the comparison of normal mode and so-called "wave" solutions of the elementary bending equation. The main comparison is based on the problem of a simply supported beam (length to depth ratio, 576:1) subjected to a step transverse loading. On the basis of experimental results for the bending moment, the superiority in convergence of the "wave" solution, for the initial response of the beam, is clearly shown. The later response is best handled with the normal-mode solution.

Reviewer believes it is important to note author's treatment of the elementary bending equation by the Heaviside wave method. It would have added to the paper to include a word of caution concerning the more general use of the elementary bending equation. Regardless of the method of solution, it is well known that

the physics of this equation restricts it from producing accurate transient solutions in problems where the short-wave lengths dominate. No mention is made of the important role the Timoshenko theory plays in these problems.

J. Miklowitz, USA

2396. Sonnemann, G., On correlation of buckling and vibration of plates, Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 124–126, Apr. 1953.

From energy considerations of plate buckling, plate vibration, and membrane vibration, a correlation hypothesis is observed: "A plate vibrating at a frequency ω can be correlated to the plate under buckling loads of equal magnitude along the edges and the correlation factor is proportional to the 'pseudo membrane frequency.' The energy stored in the plate shall be the same for both problems." Numerical examples for a clamped square plate, a simply supported rectangular plate, and a square plate with clamped and simply supported parallel edges show that the hypothesis holds. This correlation is believed to be useful for solving problems where combined edge loads and vibration occur together. G. C. K. Yeh, USA

2397. Iguchi, S., Natural frequencies and mode shapes of a free rectangular plate (in German), *Ing.-Arch.* **21,** 5/6, 303–322, 1953.

Author obtains, within the framework of the Lagrange theory, the displacement for flexural vibrations of a rectangular plate with free edges. This takes the form of an infinite series of product functions whose coefficients are, themselves, infinite series. A variety of modes of motion are considered, classified by their symmetries with respect to axes through the center of the plate and parallel to its edges, and with respect to the diagonals. Limiting his computations to a square plate, author arrives, in each case of symmetry, at an infinite determinantal equation for the frequency, which he is able to solve approximately. First few roots of this frequency equation for each symmetry are tabulated, accompanied by carefully drawn diagrams of nodal lines corresponding to each frequency-symmetry combination, as well as contour lines for some of these combinations. This remarkable paper concludes with a presentation of photographs of Chladni's figures, obtained by the author, which show excellent agreement with his analytical results. H. Deresiewicz, USA

2398. Grammel, R., Nonlinear vibrations with infinite number of degrees of freedom (in French and German), *Publ. sci. tech. Min. Air, Paris* no. 281, 45–58, 1953.

See AMR **6,** Rev. 2681.

2399. Collatz, L., Numerical determination of periodic solutions of nonlinear vibrations (in French and German), *Publ. sci. tech. Min. Air, Paris* no. 281, 195–205, 1953.

See AMR **5,** Rev. 3024.

2400. Aymerich, G., Forced periodic oscillations of nonlinear systems of two degrees of freedom (in Italian), *Atti Semin. Mat. Fis. Univ. Modena* **5,** 165–177, 1950–1951.

The set of equations considered is

$$a_{ij}\ddot{x}_j + (\partial g_i/\partial x_j)\dot{x}_j + f_i = e_i(t) \qquad i = 1, 2$$

where repeated subscripts indicate summation, dots denote derivatives with respect to t, g_i, and f_i are functions of both x_1 and x_2, and the a_{ij} quantities are constants. It is shown that a periodic solution exists provided that (a) $g(0,0) = 0$; (b) all first partial derivatives of f_i and g_i are bounded; (c) the symmetric matrix $[a_{ij}]$ is positive definite; (d) an additional condition holds concerning the behavior at large values of x_1 and x_2. Author shows that the equations considered arise both in electrical and in mechanical problems. B. A. Boley, USA

2401. Lo, H., Torsional vibration of a concentrated mass on a cantilever rectangular tube, Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 77–80, Apr. 1953.

If warping is restrained, a thin-walled tube has greater torsional stiffness, as would be expected from Saint Venant-Bredt's theory. The problem has been dealt with, e.g., by von Kármán and Chien [*J. aero. Sci.*, Oct. 1946], and by Flügge and Marguerre [AMR 4, Rev. 141], et al. The paper generalizes von Kármán's results to cover the effect of a concentrated torque (actually a vibrating mass) at an indeterminate point of the cantilever. The change of the frequency by warping restraint depends on three parameters: slenderness of the cross section, angle of the beam, and position of the mass. Three graphs give the essential results, showing that for such a tube the secondary effect is of practical importance only in a small region. K. Marguerre, USA

2402. Musikant, S., Vibration damping characteristics of glass fiber cushioning, *Prod. Engng.* **25,** 2, 167–169, Feb. 1954.

The use of glass fiber in shock and vibration damping is relatively new. Because of internal friction between fibers, the material possesses excellent damping properties. But when preloaded beyond the maximum expected service load, it also exhibits negligible permanent set. After load release, it returns almost immediately to initial dimensions. This property, augmenting resiliency, damping power, chemical inertness, moisture resistance, noncombustibility, and stability of these qualities over a broad temperature range, permits the use of the material as vibration isolators in blowers and electronic gear, shock pads, heavy machinery mountings, and protective packaging of delicate equipment and electronic components. From author's summary

2403. Slibar, A., and Desoyer, K., Vibration damping of star motors (in German), *Öst. Ing.-Arch.* **7,** 4, 309–319, 1953.

The torsional deformations of an elastic shaft connecting rotating masses, which are provided with pendulum vibration absorbers, are considered. Arbitrary periodic perturbation moments act upon the masses. The equations of motion are derived and the variations in angular velocities of the masses as well as the torsion of the shaft are calculated. It follows that each absorber can be made to satisfy a tuning condition with the result that one particular frequency of each perturbation moment will have no effect.

The general theory is applied to the special case of a star motor provided with absorber and driving a propeller by an elastic shaft. A diagram is presented giving the torsion of the shaft for frequencies differing from the particular frequency whose effect is eliminated by the absorber. A. I. van de Vooren, Holland

2404. Sawaragi, Y., Matsuda, T., and Sugawara, K., On forced vibration with a restoring force which is expressed as a function of displacement and time (in Japanese), *Trans. Soc. mech. Engrs. Japan* **17,** 64, 1–5, 1951.

The forced vibration of a system with nonlinear and varying restoring force expressed by the equation

$$m\ddot{x} + c\dot{x} + (A + 2E\cos 2\omega t)x + Bx^3 = mr\omega^2\cos(\omega t + \varphi)$$

is considered under the assumption that the solution has the approximate form $x = x_{\max}\cos(\omega t - \psi)$. Experimental results which confirm the theory are given. S. Fujii, Japan

Wave Motion, Impact

(See also Revs. 2368, 2376, 2395, 2660, 2661, 2666, 2667, 2686)

2405. **Matschinski, M., Wave propagation in an imperfect elastic medium** (in French), *C. R. Acad. Sci. Paris* **238,** 2, 203–205, Jan. 1954.

Author discusses change of shape of a stress wave. This may be due to either dispersion or attenuation. He considers how this is related to hysteresis loops and suggests that different parts of a periodic disturbance will, in general, correspond to different values of effective elastic modulus and hence will be propagated with different velocities. Author does not give details of how these effects can be treated in practice.

H. Kolsky, England

2406. **Kanai, K., and Suzuki, T., Relation between the property of building vibration and the nature of ground. (Observation of earthquake motion of actual buildings),** *Bull. Earthq. Res. Inst. Tokyo Univ.* **31,** part 4, 305–315, 1 plate, Dec. 1953.

On the basis of vibration tests on two types of reinforced-concrete buildings in two different locations, it was found that (1) the response to earthquakes is similar to the resonance curve due to sinusoidal forced vibrations; (2) the response depends on the nature of the ground, becoming smaller for softer grounds; (3) the response at roof level (fourth story) is larger than at ground level; (4) due to counterbalancing effects, responses of different buildings on different grounds are not too different.

M. G. Salvadori, USA

2407. **Goodman, L. E., Rosenblueth, E., and Newmark, N. M., A seismic design of elastic structures founded on firm ground,** *Proc. Amer. Soc. civ. Engrs.* **79,** Separ. no. 349, 27 pp., Nov. 1953.

Authors draw structural consequences of G. W. Housner's discovery that, structurally speaking, earthquakes may be considered as successions of perfectly random motions. Estimates of the maximum probable response in buildings whose response to a unit step velocity is either a sine or a square wave are obtained by means of probability theory. Comparisons are made with Housner's results and computed responses of simple structures. Corrections due to the finite duration of pulses are obtained by approximating all pulses by means of sine functions.

The conclusions reached are valid for earthquake duration long compared to the natural period of the structure. Paper does not contain illustrative examples. M. G. Salvadori, USA

2408. **Ghosh, S. K., Dynamics of plastic deformations in a bar exhibiting strain-rate effect and subjected to alternating stresses,** *Indian J. Phys.* **27,** 11, 541–546, Nov. 1953.

Author treats longitudinal vibration of uniform bar in which stress is a linear function of both strain and strain rate. Plastic deformation, as usually understood, is not considered. Results are applied to a bar fixed at one end and excited by a periodic force at the other. Comparison with work of Letherisch, Pelzer, and Wegel and Walther is presented. M. P. White, USA

2409. **Lessen, M., and Duke, C. E., On the motion of an elastic thermally conducting solid,** Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 14–18, Apr. 1953.

The conclusions of the analysis are these: (1) Thermal damping of longitudinal waves can occur in a homogeneous isotropic solid. (2) The effect of frequency (for such a solid) is the same as the effect of thermal diffusivity. (3) In particular, an extended medium has dispersive properties which are shown to be related to the thermoelastic properties. (4) Shear waves in an isotropic homogeneous medium are not thermally attenuated, as a direct consequence of the stress-strain relations when thermoelastic terms are included. (5) For small strains, damping due to thermal relaxation, thermal conductivity, and thermal inhomogeneities are basically the same phenomenon. (6) The equations of motion for a homogeneous anisotropic medium are formulated and result in a single equation for the propagation of a stress disturbance.

From authors' summary

Elasticity Theory

(See also Revs. 2366, 2380, 2409, 2424, 2426, 2429, 2433, 2443, 2481, 2482, 2493, 2504, 2539, 2716)

2410. **Horvay, G., Transient thermal stresses in circular disks and cylinders,** *Trans. ASME* **76,** 1, 127–135, Jan. 1954.

Paper consists essentially of a rewrite of a General Electric Laboratory report previously reviewed [AMR **5,** Rev. 50]. The calculated data presented in the form of 17 charts of curves are more legible in this paper and the stress and displacement data corresponding to an additional Poisson's ratio are also included. Certain technical points relating to thermal stresses are more clearly defined so that this paper may be said to supersede the original report. W. H. Hoppmann, II, USA

2411. **Chang, C.-C., and Chu, W.-H., Stresses in a metal tube under both high radial temperature variation and internal pressure,** *J. appl. Mech.* **21,** 2, 101–108, June 1954.

An attempt has been made by authors to find thermal stresses in a homogeneous isotropic metallic tube which has a high variation of temperature in the radial direction and is subject to high internal pressure. It is assumed that the equations of elasticity are satisfied throughout the region and that the elastic constants as well as the coefficient of thermal expansion depend on temperature, which itself is a function of the radial distance. With these suppositions, the equations satisfied by the stress function for plane strain and plane stress problems are deduced. The variation of temperature with the radial distance, and that of Young's modulus with temperature, are found experimentally by authors for a particular type of alloy steel, while for want of any test data, Poisson's ratio is supposed to be constant. The fundamental equations are thus formulated as the nonhomogeneous Whittaker equations and complete solutions are obtained by the method of variation of parameters in terms of Kummer series. Thermal stresses calculated for temperature variation only, without any boundary pressure, are superposed on those caused by boundary pressures alone to give a complete stress system.

An example of stress distribution in a long metallic tube of given dimensions and having prescribed temperature and pressure on the boundaries is worked out. Results obtained are compared with those deduced on the basis of constant modulus of elasticity and constant thermal expansion coefficient. S. C. Das, India

2412. **Fessler, H., and Rose, R. T., On the stress distribution in the walls of pressure vessels,** *J. Mech. Phys. Solids* **2,** 2, 127–136, Jan. 1954.

The stresses in and near the hemispherical end of a pressure vessel of uniform thickness and a mean diameter-to-thickness ratio of 10 were determined by the frozen stress photoelastic method. The methods described are applicable to any solid of rotation and can therefore be used for any shape of head and even for thicker vessels for which no satisfactory methods of calculation are known at present.

A model made from an ethoxylene resin (Poisson ratio = 0.5) was subjected to a constant inner pressure at an elevated temperature. The material used had the property of retaining the strain and birefringence after cooling. Thin slices were cut out and analyzed in a polariscope. The individual direct stresses within the three-dimensional model were calculated from the fringe patterns. The experimental results and the available theoretical analysis are compared and the agreement is good.

E. Olderin, Sweden

2413. Eubanks, R. A., and Sternberg, E., On the axisymmetric problem of elasticity theory for a medium with transverse isotropy, *J. rational Mech. Anal.* **3,** 1, 89–101, 1954.

Authors give a systematic derivation and completeness proof for the solution of problems with torsionless axisymmetry and in a medium which is transversely isotropic (the definition of transverse isotropy is given in Love's treatise). The completeness proof is for the above stated solutions due to S. G. Lekhnitskiĭ [*Prikl. Mat. Mekh.* **4,** 3, p. 43, 1940]. The derivation and proof depends upon a generalization of Almansi's theorem of solutions to the polyharmonic equation, i.e.,

$$\prod_{i=1}^{n} \nabla_i^2 F_n = 0$$

The theorem is a representation theorem for the latter equation.

The stress-strain relations are derived for the medium under consideration by the usual means of the strain energy function. These relations contain five independent elastic constants. Computations using the positive definiteness of the strain energy function lead to certain inequalities on these constants.

The introduction of cylindrical coordinates leads to stress-strain relations in this new coordinate system, and, using the equations of equilibrium in the absence of body forces, a system of differential equations is derived for the displacements.

Following Lekhnitskiĭ, two functions relating to the displacements, similar to the Airy stress function, are introduced and detailed computations lead to a representation of these functions. The completeness of the solution is contained in this derivation. It is shown, by specializing certain parameters, that Lekhnitskiĭ's solution is obtained. In particular, if the medium is strictly isotropic then the solution reduces to Love's. It is interesting to note that this problem has been essentially dormant since 1940, although recently several English authors have obtained results similar to Lekhnitskiĭ, assertedly by independent means. More details on this problem can be found in Lekhnitskiĭ's text ["Theory of elasticity of an anisotropic solid," 1950; see AMR **5,** Rev. 1014]. Undoubtedly this text contains further references.

Authors' new representation should give a better insight into this interesting and somewhat difficult problem. It would be worth while to apply the results to an already known problem in order to see the power of the new representation.

J. J. Brandstatter, USA

2414. Schaefer, H., Stress functions of the three-dimensional continuum and of the elastic body (in German), *ZAMM* **33,** 10/11, 356–362, Oct./Nov. 1953.

The tensor field of stress, which is a solution of the conditions of equilibrium and the conditions of compatibility, can be represented by six stress functions, building a tensor of second class, in such a way that the equilibrium conditions are satisfied by any choice of the stress functions. There exist some analogies to the gravitation theory of Einstein. In the special case of the isotropic elastic body, the known representation of the stress functions of Boussinesq and Neuber is obtained. H. Neuber, Germany

2415. Berthier, G., Reduction of strain in bent bodies of arbitrary cross section (in French), *Gén. civ.* **130,** 21, 413–414, Nov. 1953.

2416. Adkins, J. E., Green, A. E., and Shield, R. T., Finite plane strain, *Phil. Trans. roy. Soc. Lond.* (*A*) **246,** 910, 181–213, Oct. 1953.

Using a general coordinate system, a general theory of plane strain superposed on uniform extension that can be employed in solving problems of large elastic deformation of isotropic materials is developed by authors. Besides the assumption of plane strain, no other condition is imposed on the form of the strain energy function. Assuming that the matter is incompressible, the method is used in obtaining exact solutions of a few problems, some of which were previously solved in a different manner. Problems discussed are those of flexure of a cuboid, flexure of an initially curved cuboid, and deformation of a cuboid under generalized shear.

For problems for which the exact solutions cannot be found, a method of successive approximation is then developed. As before, the material is supposed to be incompressible, and attention is confined to terms of the first and second orders only, though it is observed that the process may be continued up to any degree of approximation. In problems of plane strain, it is found that much advantage is gained if stresses and displacements are expressed in terms of complex potential functions. But in finite deformation problems, the complex coordinate system may be related either to points in the undeformed body or to points in the deformed body. Hence both cases are considered separately. Finally, the theory is applied to solve problems of an infinite body which contains a circular hole or a circular rigid inclusion, the body being subjected to a uniform tension at infinity. Reviewer believes that the method will be found useful in solving other problems of similar type. S. C. Das, India

2417. Cowan, H. J., The theory of torsion applied to reinforced concrete design, *Civ. Engng., Lond.* **48,** 567, 568; 827–829, 950–952, Sept., Oct. 1953.

2418. Mindlin, R. D., Force at a point in the interior of a semi-infinite solid, Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 56–59, Apr. 1953.

Author gives a direct solution by the use of potential theory to the problem he solved previously. See *Physics* **7,** 195–202, 1936.

E. Saibel, USA

Experimental Stress Analysis

(See also Rev. 2457)

2419. Morice, P. B., and Base, G. D., The design and use of a demountable mechanical strain gauge for concrete structures, *Mag. Concr. Res.* no. 13, 37–42, Aug. 1953.

The described 8-in. gage length lever and dial-type gage does not offer any basically new approach. However, the careful design of the presented device and its simplicity are important merits. The use of mild-steel reference disks cemented to the surface of concrete specimens is a standard procedure in the reviewer's practice. D. Vasarhelyi, USA

2420. Massonnet, Ch., Experimental investigation of structures by means of small scale models, without the use of microscopes (in French), *Bull. Centre Étud. Constr. genie civ. Hyd. Fluviale* **6,** 405–453, 1953.

Paper discusses and describes Eney's deformeters. Author

points out that only very small deflections are obtained by Eney's method, necessitating the use of optical devices of considerable power. A new method, using large elastic deflections, is developed, and it is shown that the errors involved are of only the third order of magnitude. Because of the larger deflections involved, only a low-powered magnifying glass is needed as an optical aide. Several applications are made to simple structures and also to a complicated three-span arch bridge with stiffeners. Less than 2% error is obtained. Detailed description of the deformeter is given and complete instructions for its operation are set forth.

Reviewer's opinion is that this is an ingenious addition to the experimental method of investigating structures.

T. A. Hunter, USA

2421. **Heilig, R., Composite bridge decks under torsion loading** (in German), *Stahlbau* **23,** 2, 25–33, Feb. 1954.

Worked-out examples are presented, based on an earlier paper which gives the theory. Load-carrying element is formed of parallel I-beams supporting a concrete slab, I-beams and slab forming a single load-carrying composite beam. Examples cover simply supported and continuous-over-several-spans systems subjected to eccentric loads that produce torsion. Bending moments, twisting moments, and stresses are evaluated.

G. W. Housner, USA

Rods, Beams, Shafts, Springs, Cables, etc.

(See also Revs. 2394, 2395, 2408, 2445, 2456, 2472, 2490)

2422. **Preti, E., On the calculation of a grid of rectilinear beams in aircraft construction** (in Italian), *Aerotecnica* **33,** 6, 418–423, Dec. 1953.

Grillages consisting of orthogonal simply supported beams, under the action of a uniformly distributed load over their entire plane and axial compression loads on the beams, are concerned. As in a former paper by Minelli [title source **11,** 1936], assumption is made that grillage can be represented by a continuous curtain of a double infinity of beams, and the method of minimum potential energy is adopted. Strain energy and potential energy of applied loads are expressed in terms of deflection of two orthogonal differential strips. No torsional resistance is considered. Integration is made possible by developing deflection into a cosine double Fourier series. A numerical example is given showing rapid convergence of the series, thus allowing the development to be restricted to the first term.

F. Correia de Araújo, Portugal

2423. **D'Appolonia, E., Curvilinear co-ordinates for the numerical solution of a notched bar in tension,** Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 60–65, Apr. 1953.

The numerical solution of stress computation of a cylindrical notched bar in tension is given by using finite difference expressions in two steps. In the first step a rectangular network is used, which gives satisfactory results only at points away from the notch. The so-computed strain or stress values represent the boundary conditions for the second step with the use of a curvilinear network, a step which refines the computation in the region of the notch. The outlines of the theory of curvilinear network are given.

F. Stüssi, Switzerland

2424. **Lein, G., Torsional rigidity of beams with cross-shaped cross section** (in German), *Ing.-Arch.* **21,** 5/6, 352–364, 1953.

The torsional stiffness of rods whose section is cross-shaped, that is, a central square with four projecting legs, is determined to lie between two bounds such as

$$b^4[15.760 + (8/3)(\lambda_1 + \lambda_2 - 6.5)] < J_t < b^4[15.800 + (8/3)(\lambda_1 + \lambda_2 - 6.5)]$$

where $2b$ is the width of each leg, (λ_1, b, $\lambda_2 b$) the over-all length of each pair of legs, and J_t the stiffness. It is assumed that each leg is greater in length than five times its width. Moreover, there are sharp re-entrant corners. When the corners have rounded fillets, the stiffness increases, the increase largely given by a change in the first term of inequality. The analysis requires considerable numerical work.

D. L. Holl, USA

2425. **Hahn, L., Beam on continuous elastic support** (in French), *Publ. int. Assn. Bridge struct. Engng.* **13,** 175–196, 1953.

Instead of integrating differential equation of the fourth order, author uses for calculation of beams on elastic supports the relation of Bresse for the elastic line. He deduces recurrence relation for the ordinates of the elastic line as a function of two consecutive values of ground reactions and of bending moments. He supposes a constant relation of the ordinate of the elastic line and of the support reaction. The calculation is made by trial, starting from two chosen values of bending moment and of reaction of support. From three elastic lines obtained in this manner, the exact parameters are determined which satisfy the boundary conditions. Four examples, the last for a beam of variable section and breadth, show that this method gives practically precise results quickly.

Z. Bažant, Czechoslovakia

2426. **Basilevich, V., Shearing stress in bending of I beams,** *Acad. Serbe Sci. Publ. Inst. math.* **5,** 21–28, 1953.

Paper presents solution for shearing stresses in a cantilever I-beam loaded with a concentrated load on the end. The shearing stresses are independent of normal stresses and are the same in all cross sections. They are expressed in terms of a stress function satisfying the Laplace equation. Two different series expressions for stress function are assumed, one for the flange, the other for the web, and the constant coefficients in the series are chosen to satisfy the boundary conditions. A numerical example is also given. The presentation could be made clearer.

A. Hrennikoff, Canada

2427. **Bennett, E. W., The calculation of deflections and bending moments at the supports of prestressed beams,** *Concr. constr. Engng.* **48,** 11, 343–348, Nov. 1953.

2428. **Clark, L. G., Deflection of laminated beams,** *Proc. Amer. Soc. civ. Engrs.* **79,** Separ. no. 331, 17 pp., Nov. 1953.

Main part of paper consists of computation of deflection of beam consisting of two laminations which are joined together at a number of equally spaced points (rivets, bolts, spot welds). Slip at attachment points and friction between laminations are neglected. Some simple examples are given and comparison is made with some experimental results. Choice of number of joints for obtaining desired deflection is discussed and procedure for analyzing beams composed of more than two laminations is indicated.

F. J. Plantema, Holland

2429. **Eringen, A. C., Thermal stresses in a multiple layer beam,** Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 69–73, Apr. 1953.

Using the principle of minimum total potential, author studies a three-layer beam subjected to axial and transverse forces, moments, and arbitrary temperature distribution. All layers have different thicknesses and materials. Shear deformability

effects are taken into account. Four linear differential equations are obtained and twelve boundary conditions. The equations are solved for the practical problem of the bending of a sandwich cantilever beam due to temperature gradient across the thickness. Classical beam approach, with no shear deformation, is an approximation of the present theory and gives considerable difference. W. L. Esmeijer, Holland

2430. **Newton, J. A., and Allen, C. H., Valve-gear fundamentals for the large-engine designer,** *Trans. ASME* **76,** 2, 137–148, Feb. 1954.

2431. **East, F. G., Proposal for a standard design for general industrial coarse-pitch cylindrical worm gearing,** *Trans. ASME* **76,** 2, 163–168, Feb. 1954.

2432. **Maddock, J., Balanced design for case-hardened gears,** *Prod. Engng.* **25,** 3, 202–207, Mar. 1954.

Plates, Disks, Shells, Membranes

(See also Revs. 2396, 2397, 2401, 2446, 2450, 2470)

2433. **Conway, H. D., Stress concentration due to elliptical holes in orthotropic plates,** *J. appl. Mech.* **21,** 1, 42–44, Mar. 1954.

Solutions of plane stress problems of elliptical hole in infinite orthotropic sheet are obtained by transformation from corresponding problems in which hole is circular. Two special problems are solved: (a) Hole loaded by pair of concentrated forces at ends of major or minor axis, and (b) hole in sheet subjected to uniform tension. A. E. Green, England

2434. **Naghdi, P. M., and Rowley, J. C., On the bending of axially symmetric plates on elastic foundations,** Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 119–123, Apr. 1953.

The Reissner theory, which takes into account the effect of transverse shear and employs more general boundary conditions than those of Kirchhoff, is used. The reaction of the foundation at each point is assumed to be proportional to the deflection at that same point and independent of deflections at all other points. Two cases of infinite plates are considered. In one case, deflections and slopes at the boundary of a small circular hole are prescribed; in the other case, a uniform load is distributed over a small circular area. Results for moments, shears, and deflections at the edge of the circle show considerable difference between the Reissner and the classical theories if the radius of the circle is not more than twice the thickness of the plate. G. Pickett, USA

2435. **Ihlenburg, W., Plates supported by elastic girders** (in German), *Stahlbau* **22,** 8, 9; 169–171, 209–214, Aug., Sept. 1953.

Conventional analysis, together with numerical results, is given for the elastic deformation of plates reinforced by girders and subjected to the action of transverse loads.

H. G. Hopkins, USA

2436. **Ericksen, W. S., The bending of a circular sandwich panel under normal load,** *For. Prod. Lab. Rep., U. S. Dept. Agric.* no. 1828, 36 pp., June 1953.

Author obtains design formulas for the deflections and stresses in a circular sandwich panel which is acted on by either a uniformly distributed normal load or by a normal load applied to a solid concentric circular insert. The edge is either clamped or simply supported.

The assumptions on which the theory is based are: (a) That the core and facing materials are isotropic; (b) that the bending moment taken by the core is negligible; (c) that the transverse shear stress taken by the core is constant over the thickness; (d) that the transverse shear stress taken by the facings is negligible.

The formulas obtained are fairly complicated and only apply when the deflections are small. No attempt is made to compare the theoretical formulas with the results of experiment.

D. M. A. Leggett, England

2437. **Hamel, G., On the theory of thin plates of low curvature** (in German), *ZAMM* **33,** 4, 138–143, Apr. 1953.

In a short paper which runs the gamut of mathematics from algebra through partial differential equations to vector analysis, and of engineering from mechanics through elasticity to virtual work, author points out that both the classical theory of Kirchhoff and the modern theory of Reissner have defects with regard to the bending of thin plates. Both have attempted to reduce to two dimensions a problem which is essentially three-dimensional and have failed to satisfy one of the inherent boundary conditions.

He proposes that, for this case, the shear term in the differential equations of the classical theory should be replaced by a torsional shear (also a partial differential term in his equations). This alters the sign of one term in the classic equations of equilibrium since it no longer makes the sum of the torsional shears in the x and y directions equal to 0.

Author states that he is synopsizing for the most part a chapter from his book on technical mechanics. At the same time, he is expanding (although not enough in detail to be followed) certain of the proofs inherent in his work.

This tendency on the part of elasticians to omit satisfaction of a boundary condition has been noted from time to time on the part of foreign engineers trained in the mathematical theory of elasticity, sometimes in print and sometimes verbally. It is possible that here is a point which bears further investigation by American scientists. J. R. Bruggeman, USA

2438. **Kennard, E. H., The new approach to shell theory: circular cylinders,** *J. appl. Mech.* **20,** 1, 33–40, Mar. 1953.

Taking Epstein's basic work on elastic vibrations in plates and shells [*J. Math. Phys.* **21,** p. 198, 1942; also Chien, W. Z., *Quart. appl. Math.* **1,** p. 297, 1943; **2,** pp. 43, 120, 1944], author proceeds to construct expressions for the distributions of stress and displacements. From these, stress resultants are calculated. The principal effects of external load on the faces of the shell are included, and the validity of the approximation and practical applications of results are discussed. From author's summary

2439. **Krettner, J., Contribution to the application of tensor calculus for shell calculation** (in German), *Ing.-Arch.* **21,** 5/6, 339–345, 1953.

The expressions for covariant and contravariant metric tensors, for the displacement, distortion, and for the deformation tensors are derived for a middle surface of the shell and for the shell. All steps of the derivations are clearly shown. An example applied to a cylindrical shell illustrates the simplification obtained by the use of this method. W. Ornstein, USA

2440. **Müller, W., On the theory of continuous foundation plates and flat slab floors (Pilzdecken) with rectangular loading or supporting faces** (in German), *Öst. Ing.-Arch.* **6,** 5, 404–417, 1953.

For a plate on an elastic foundation (assuming Winkler's hypothesis) and loaded by equidistant equal loads acting on rectangular faces, as well as for a flat slab floor on rectangular supporting faces, Lewe has represented the deflection by double series

Bauingenieur 1920, 1922, 1923]. Present author reduces the double series to single series using a formula of Kneser [AMR **6**, Rev. 1232]. The case of the flat slab floor is deduced by a limit transition from the case of the foundation plate.

The method is illustrated by two examples: the foundation plate equally loaded in parallel equidistant stripes, and the flat slab floor on point supports. In a later paper, author demonstrates the calculation of moments [AMR **6**, Rev. 3699].

E. Seydel, Germany

2441. **Moe, J., On the theory of cylindrical shells, explicit solution of the characteristic equation, and discussion of the accuracy of various shell theories,** *Publ. int. Assn. Bridge struct. Engng.* **13**, 283–295, 1953.

Dischinger's characteristic equation for cylindrical shells is solved approximately in explicit form. Consequent numerical calculation is reduced to a minimum and the roots are shown to be very accurate. Results are compared with those found from characteristic equations used by other writers. Author concludes that equations of Aas-Jakobsen, Lundgren, Jenkins, and Zerna are sufficiently accurate for all practical purposes. Equations of Finsterwalder and Schorer only yield reasonable values of the roots for very long shells. A. E. Green, England

2442. **Krettner, J., Application of tensor calculation to the theory of rotational shells** (in German), *Öst. Ing.-Arch.* **7**, 3, 246–254, 1953.

Using tensor notation, author presents differential geometry of a surface of revolution and derives for the middle surface of a shell of revolution the expressions for displacements, stresses, strains, and changes of curvatures. He utilizes the middle surface of a shell as a surface of reference and derives similar expressions for a point which is outside the middle surface. Finally, the equations of equilibrium are derived and presented in two alternative forms. Tensor notation has no engineering applications up to now.

T. Leser, USA

2443. **Botto, P., Calculation of centrifugal stresses in conical disks and in disks of constant thickness with radially varying specific weight** (in Italian), *Aerotecnica* **33**, 4, 291–296, Aug. 1953.

In order to facilitate the analysis of compressor impellers in which the presence of radial blades corresponds to a virtual variation of specific weight, the centrifugal stresses in conical disks (thickness varying linearly with radius) are determined, assuming the specific weight varies with the radius r according to a polynomial in r with integral exponents. The results are tabulated and plotted. The same problem is then solved for the case of a disk of constant thickness in which the variable density is expressed as a polynomial in r with exponents no longer necessarily integral. Finally, a numerical example is worked out for an impeller disk of a centrifugal compressor, decomposing it into partially conical disks.

From author's summary by F. DiMaggio, USA

Buckling Problems

(See also Rev. 2396)

2444. **Hoff, N. J., Buckling and stability,** *J. roy. aero. Soc.* **58**, 517, 3–52, Jan. 1954.

In this most important paper, which was delivered as the 41st Wright Brothers Lecture of the Royal Aeronautical Society, Dr. Hoff primarily details the research investigations which he and his group at Brooklyn Polytechnic Institute have conducted on dynamic buckling of columns. The subjects covered range through columns in Greek and Roman structures; Euler's theory for elastic columns; the first era of the tangent modulus controversy (1889–1910), covering contributions of Considere, Engesser, von Kármán, and Southwell; and the use of struts by the Wright brothers in the construction of the first powered aircraft. Starting with the second era of the tangent modulus controversy (1948–), which was apparently revived by Shanley, Dr. Hoff discusses theoretical and experimental investigations of columns containing initial imperfections in a testing machine in which the loading head moves with a prescribed velocity. Among the features investigated in the dynamic buckling process are: Elastic buckling [Hoff, AMR **4**, Rev. 2434]; elastic column tests [Hoff et al., AMR **5**, Rev. 76] in which strains, load and head displacement histories were obtained; short column tests; short column theory based on a power law for the stress-strain relation; and investigation of the effect of the testing-machine elasticity upon short column behavior. Further column investigations include: behavior under dead-weight loading, rapid loading of linear and nonlinear columns, and creep buckling based on a steady-state creep law.

In discussing the significance of the buckling load to the engineer, plates and shells are discussed in relation to elastic and plastic buckling of columns. An enlightening philosophical discussion of various criteria for theoretical buckling as compared to experimentally observed behavior concludes the presentation.

One of the significant features of considering buckling as a dynamic process is a recognition of the importance of the testing-machine elasticity upon failure of the column. For an elastic column, failure occurs gradually; for a plastic column, failure is a sudden or snap process. Study showed that the requirements for a snap process are a nonlinear stress-strain relation and an elastic testing machine. For certain combinations of these factors, the load-end shortening relation displays features which in a broad sense resemble those of a circular cylinder under compression, and thus conditions for snap buckling occur.

Because of the current tangent modulus controversy, it is important that the contributions of this paper should not be overlooked by any worker in applied mechanics. A theory for column behavior of both elastic and plastic columns has to have a consistent basis; one cannot select one criterion for elastic columns and another for plastic columns in order to bring theory into agreement with experimental results. This apparently has been the underlying cause of the recent tangent modulus controversy. Dr. Hoff notes that, in the Eulerian sense, "the buckling load is the load under which the system is in equilibrium, not only in a single configuration of the deformations but also in neighboring configurations." With this definition, the reduced modulus formulation is the only correct model for plastic buckling of the column. If bending and axial loading proceed simultaneously, as proposed in the Shanley model, so that strain reversal cannot occur, any stability investigation of neighboring equilibrium configurations is meaningless since the bent form is the only stable configuration. Dr. Hoff notes, ". . . acceptance of the tangent modulus as the correct buckling load is equivalent to rejection of the classical concept of stability."

To obtain the proper perspective of the contributions of this paper, one may ask if the results obtained change the method of calculation by the design engineer of the allowable strength of column and plate elements. The answer to this must be "no." From the standpoint of those who are interested in the fundamental physical phenomenon of buckling as well as the mathematical formulation, however, this paper does present an outstanding achievement in providing a deep insight into the physical process of buckling, together with detailed theoretical treatment of this process.

This paper provides a consistent investigation of the elastic and plastic buckling process under conditions inherent in a testing machine to determine if the foundational assumptions of the Eulerian theory are duplicated in the test procedure. Apparently there are basic points of disagreement between the two; and, since the assumptions of classical theory are not fulfilled, the experiment cannot test the theory. The dynamic buckling approach has the experiment as its basis and provides a realistic approach to the physical process of buckling. G. Gerard, USA

2445. Hill, H. N., Lateral buckling of channels and Z-beams, *Proc. Amer. Soc. civ. Engrs.* **79,** Separ. no. 334, 14 pp., Nov. 1953.

Author presents results of investigations of lateral buckling of channel and Z-sections of extruded aluminum alloy 17S-T6.

To provide stable test setup, beams were bolted in pairs to end frames and loaded so as to subject unsupported length to pure bending. Lengths from 65 in. down to 20 in. were tested. Tensometer measurements of flange stresses at heel and toe were in good agreement with computed stresses, small differences between heel and toe of compression flange being attributed to slight initial lack of straightness.

Only the longer lengths buckled in the elastic range. End restraints due to bolted connections proved incomplete. Comparing test results for 65-in. members with theory given by J. N. Goodier, author estimates effective unsupported length as $0.59L$ for channels and $0.76L$ for Z-sections.

Author calls attention to the importance of the torsion-bending factor C_s. He gives various approximate formulas for it but suggests that it should be tabulated with other properties of standard sections.

Reviewer noted two errors. In table 1 of properties of test sections headings, channel and Z-sections should be interchanged. In Eq. 6 the factor $4-6A_f/A$ should be enclosed in a bracket.

A. Burn, Australia

2446. Norris, C. B., Boller, K. H., and Voss, A. W., Wrinkling of the facings of sandwich construction subjected to edgewise compression, *For. Prod. Lab. Rep., U. S. Dept. Agric.* no. 1810-A, 27 pp., June 1953.

Report deals with the compressive wrinkling stresses in the facings of sandwich construction having honeycomb cores. It is shown that the wrinkling is influenced by the cell size of the honeycomb core. Test results showing the accuracy of the equations are reported. C. T. Wang, USA

2447. Laponche, R., Some cases of graphical analysis of stresses in a pillar carrying an eccentric load. Extension to the plastic region (in French), *Ann. Inst. tech. Bât. Trav. publics* **6,** 66, 599–608, June 1953.

Paper refers to eccentrically loaded cross sections of a material without tensile strength. In a rectangle or parallelogram, the region under compression may be a triangle, quadrilateral, or pentagon, according to the position of the load. This is analyzed for the elastic state. If the material becomes plastic, a constant stress but restricted ultimate strain is assumed. Computations for this case are outlined for symmetrical cross sections loaded in the symmetry axis. H. Craemer, Germany-Pakistan

2448. Masur, E. F., Post-buckling strength of redundant trusses, *Proc. Amer. Soc. civ. Engrs.* **79,** Separ. no. 332, 14 pp., Nov. 1953.

The load-carrying capacity of redundant rigid-jointed trusses after the trusses have buckled in their own plane is investigated. It is shown that (unlike similar statically determinate frameworks) such trusses buckle under increasing external forces, which generally approach limiting values as buckling progresses. Computation of the ultimate load is facilitated by use of two theorems establishing upper and lower limits of the ultimate loads. Thus, the carrying capacity of the truss can be estimated by "surrounding" the unknown load between two easily calculable values. Of these limits, the lower bound can be computed to any desired accuracy.

See also author's paper on the same subject [AMR **7,** Rev. 2134]. From author's summary by S. E. Kindem, Norway

2449. Carlson, R. L., The behavior of perfect columns at elevated temperatures, Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 184–185, Apr. 1953.

Conditions necessary for instability of perfectly straight axially loaded columns exposed to elevated temperatures are discussed. It is concluded that a perfect column that is loaded to a value of load which is less than its tangent modulus load will become unstable in time only if the static stress-strain properties are affected by either the creep that has occurred, or by metallurgical change. It is also concluded that if such instability does occur, the criterion for instability will be given by a reduced- or double-modulus-type consideration when the column load is constant with time. From author's summary

2450. Radok, J. R. M., General instability of simply supported rectangular plates, *J. aero. Sci.* **21,** 2, 109–116, Feb. 1954.

Paper considers lateral buckling of thin plates with idealized line stiffeners when plate is compressed in one direction. The characteristic equations are derived directly from the equilibrium equations for four cases: (a) plate with discrete stringers alone, (b) with discrete ribs alone, (c) with both discrete stringers and discrete ribs, and (d) with distributed stringers but discrete ribs. The method leads to a determinantal equation, the order of which equals the number of discrete stiffening members except in case (c), for which an infinite determinant is obtained.

D. Young, USA

2451. Sattler, K., Deflection methods for solving stability problems (in German), *Bautechnik* **30,** 10, 11; 288–294, 326–331, Oct., Nov. 1953.

Author applies deflection methods to obtain approximate solutions of a range of buckling problems. For single members, either solid, latticed, or batten-plated, deflection is obtained as $f = \int mMdx/EI$, where $M = Py$.

The shape of the y-curve is either assumed to be a simple curve such as $y = f \sin \pi x/l$, or the length is divided into a number, say 8, equal parts, with deflections y_1, y_2, y_3, y_4. In latter case, polygonal approximation with constant EI for each section is used in computing integral, and buckling condition is obtained as fourth-order determinant $D = 0$. Solution proposed is to plot D against P, selecting smallest root.

For latticed and batten-plated members the curve $y = f \sin \pi x/l$ is assumed and allowance made for effect of web members. Formulas obtained for buckling loads are identical with those of Bleich.

Most interesting part of paper deals with buckling of rectangular building frames. Procedure is to assume sidesway f for a single-story frame or f_1, f_2, f_3, etc., for multistory frames, and to apply ordinary moment distribution methods to distribute the total frame moment ΣPf. These distributed moments are then used to compute deflections. A correction term for the additional bending moments in the columns is added, using a simple form of assumed curve.

Author notes that, in calculating deflection integrals, the factor m may be taken as that of any possible statically equivalent base

system. For instance, with columns fixed at the base, the deflection at any floor level may be calculated for one column only, using only the part of the column below that floor, with the appropriate m.

For buckling beyond the elastic range, author suggests use of modified modulus in accordance with DIN 4114, July 1952.

Author claims that his methods will give buckling loads within 5% of the true values on the safe side, and with very considerable reduction in amount of computation involved. Reviewer has compared solution by author's method with exact solutions for a simple portal with one or both posts loaded and found claims substantiated, provided K(beam) > K(column). However, with abnormal proportions, K(column) = $4K$(beam), author's method was over 20% low, probably due to assumed column curve overestimating bending moments in column.

For frames of normal proportions, author's method appears to have considerable value. A. Burn, Australia

Structures

(See also Revs. 2393, 2406, 2407, 2417, 2420, 2421, 2422, 2427, 2435 2440, 2448, 2451, 2469, 2480, 2539, 2700)

2452. **Lazarides, T. O., Statical indeterminacy—the foundation of prestressed concrete design,** Canadian Conf. on Prestressed Concrete, 1954, University Extension, University of Toronto, G-1–G-10, 13 figs.

Author advocates the idea of statical indeterminacy of the structural material to point out the following important idea: In statically determinate reinforced concrete, geometric properties of the section are almost determined by the load and the span, while in indeterminate structures carry-over moments which may be changed by the designer, by juggling with the ratios of the moments of inertia of contiguous units, allow a greater freedom of choice. Similarly, in a prestressed beam where juggling may be carried out not only in the amount and location of prestress but also in the use of the dead load and other factors, a much freer design is possible. The term statically indeterminate, whatever its true extent, is, however, associated with a state of stress which is influenced by inner conditions which require the lifting of the indetermination by other considerations and was thus generally misunderstood. The paper is provocative and useful in comprehending the philosophy of prestressed-concrete design if it is kept in mind that the author does not give to the term indetermination the usual meaning and if design is considered to be the elaboration of the structure and the realization of its elements, not the actual mathematical analysis. R. Quintal, Canada

2453. **Fealdman, H., An introduction to prestressed concrete theory,** Canadian Conf. on Prestressed Concrete, 1954, University Extension, University of Toronto, C-1–C-20, 20 figs.

In the author's own words, this paper presents a concise review of the fundamental theoretical principles underlying the present-day development of prestressed concrete and is intended as an introduction only. R. Quintal, Canada

2454. **Magnel, G., Significant features of prestressed concrete,** Canadian Conf. on Prestressed Concrete, 1954, University Extension, University of Toronto, F-1–F-12, 25 figs.

The writer is a world-renowned authority in prestressing and the paper is a vulgarization of his own highly theoretical work and experience in the field. Some remarks almost lost in the context would have gained by being further detailed, especially as regards effect of temperature fluctuations. Some personal observations, such as criticism of the American emphasis on mass production which complicated the procurement of some fittings, could have been omitted, such as some accusation against the contractor's concreting practice on the Walnut Lane Bridge.

R. Quintal, Canada

2455. **Shearwood, F. P., The stabilization of suspension bridges,** *Engng. J., Montreal* **37,** 1, 1–6, Jan. 1954.

The action of suspension bridges and their unique behavior as compared with all other types of bridges, when subjected to wind force, are discussed. To modify these differences, a change in the stiffening system is proposed. From author's summary

2456. **Gilg, B., Influence of edge beams on plate bridges** (in German), *Schweiz. Bauztg.* **71,** 48, 701–705, 2 pp. of graphs, Nov. 1953.

The interaction is analyzed between a rectangular thin elastic plate, freely supported along two of its parallel edges, and two reinforcing edge beams provided along the nonsupported edges; those edge beams, the center lines of which are not in the middle plane of the plate, are assumed to be able to carry only vertical bending moments. Biharmonic equations are obtained for the vertical deflection of the plate as well as for the forces in its middle plane, and are solved by infinite series. These solutions are evaluated for symmetric edge beams and uniform loading of the plate, and presented in the form of diagrams indicating the effect of the edge beams on moments and forces in the plate as functions of its span-to-width ratio, with the depth ratio of beam to plate as a parameter. A. M. Freudenthal, USA

2457. **Omura, H., Measured stresses in some steel highway bridges of plate-girder type** (in Japanese), *J. Soc. civ. Engrs. Japan* **38,** 6, 8–12, June 1953.

Stresses in some steel highway bridges of plate-girder type were measured by electric resistance strain gages and compared with calculated ones. The bridges were loaded by two different kinds of trucks. Measured stresses in the main girders of new bridges were about 50%, those in stringers were about 10–30%, those in cross beams were 60% or 30%, according to the type of structure, of the calculated ones. T. Mogami, Japan

2458. **Waling, J. L., Least-weight proportions of bridge trusses,** *Univ. Ill. Engng. Exp. Sta. Bull.* no. 417, 56 pp., 1953.

The determination of least-weight proportions of bridge trusses lends itself to mathematical investigation. The procedure here presented consists of the adaption of the theory of maxima and minima to solving for the proportions of a truss outline, such that the volume of metal in the truss is a minimum. Explanations are given of the assumptions and approximations upon which the calculations are based and concerning the resolution of complications interspersed by modern design specifications.

Calculations were performed to determine least-weight proportions and theoretical least weights of simple span, through-type, double-track, open-timber-deck railway bridges having 68 different combinations of truss type, panel length, span length, and live load. In general, the results of these calculations show that weight savings can be accomplished by designing these trusses somewhat deeper than is normally done by present-day designers.

From author's summary by E. D'Appolonia, USA

2459. **Callard, E. J., Design and construction of welded portal frame warehouse building designed by the plastic method,** *Struct. Engr.* **32,** 1, 30–37, Jan. 1954.

Paper briefly describes the design and construction of a simple

portal frame building, for which the steel framework was designed by the plastic method. Figures are given to show the economy achieved in the usage of steel over that which might have been used had the framework been designed by elastic methods, and the simple construction of the connections between the rafter and column members is illustrated. From author's summary

2460. Wood, R. H., A derivation of maximum stanchion moments in multi-storey frames by means of nomograms, *Struct. Engr.* **31,** 11, 316–328, Nov. 1953.

Framed structures which include members carrying substantial direct loads can be analyzed by modified moment-distribution or slope deflection [see e.g., "Statically indeterminate structures," L. C. Maugh, John Wiley & Sons, Inc., 1946]. Author has developed a simplified procedure by which the final moments in a column forming part of a rigid frame can be computed with the use of a nomogram. A separate diagram is required for each value of $\alpha = (P_{euler}/EI)^{1/2}$. To use the nomogram, the boundary conditions must be known in terms of the degree of fixity at each end and the out-of-balance fixed-end moments fed in from the beams. The answers are in the form of the final end moments after the joints have been allowed to rotate. Extension of the procedure is complementary to one developed by M. R. Horne [title source **28,** 5, 109–115, May 1950] for finding the distributed moments in beams. Together the two procedures should be extremely useful in the design of multistory multibay rigid frames carrying vertical loads only, because the final answers appear to be less sensitive to errors in the initial estimate of the stiffness of members than is the case with moment distribution.

L. Schenker, USA

2461. Csonka, P., Torsion analysis of braced transmission towers with free tops (in German), *Acta Techn. Hung. Budapest* **7,** 1/2, 147–158, 1953.

Paper gives the analysis indicated in the title for bracings of the N-type only. It is supposed that the tower base is anchored in a rigid block and that its upper end is free. The transverse bracing at the top is supposed to be rigid or to consist of an elastic Andrew cross. This paper follows a similar study by the same author [title source, **6,** 3/4, 387–397, 1953], where the case of two rigid end blocks was considered. Ch. Massonnet, Belgium

2462. Csonka, P., Structural analysis of truncated pyramid frames, *Acta Techn. Hung. Budapest* **7,** 3/4, 507–518, 1953.

Paper contains the structural analysis of braced towers of rectangular cross section and truncated pyramidal form, covering statically determinate structures, all braces of which lie in the lateral faces of the tower. The structures analyzed belong to the six most usual types of bracing; in each of them, all diagonals of one braced side are supposed to form the same angle with the legs of the truncated pyramid.

Bar stresses are determined in simple torsion as well as for the case where forces of equal magnitude but of alternately opposing sense are acting on one or the other of the structure's terminal surfaces. For these three loading cases, tabulations are presented in which formulas of bar stresses produced in members between the two terminal surfaces are available for computation. The formulas are not valid for bar stresses produced in members lying in the planes of the two terminal surfaces.

From author's summary by Ch. Massonnet, Belgium

2463. Csonka, P., Deformation of truncated pyramid frames, *Acta Techn. Hung. Budapest* **7,** 3/4, 465–474, 1953.

This paper should be read after author's other paper (see preceding review). It determines the warping of the terminal surfaces of truncated pyramidal braced towers, produced by simple torsion or by forces of equal magnitude and parallel to the axis of the tower, but of alternately opposite sense, acting upon one or the other terminal surface of the structure.

In the calculations, the bars lying in the planes of the terminal surfaces are considered rigid, and the warping of the terminal surfaces is characterized by the dislocation of two contiguous corners in the direction of the axis of the pyramid. In case of simple torsion, the deflection thus interpreted has the same value on both terminal surfaces. The formulas presented also afford facilities for the determination of the warping of terminal surfaces of prismatic space frames.

From author's summary by Ch. Massonnet, Belgium

2464. Selberg, A., On the bearing capacity of Voussoir arches, *Publ. int. Assn. Bridge struct. Engng.* **13,** 321–326, 1953.

The investigation shows the dominant influence of the superstructure on the bearing capacity of masonry arches. The improvement of the superstructure—for instance, by injection of cement—will very often be the cheapest and most convenient method for strengthening old arch bridges.

From author's summary

2465. Noton, B. R., Structural aspects of swept-back wings, *Aircr. Engng.* **25,** 297, 330–343, Nov. 1953.

Paper reviews research on the title subject conducted in Sweden and is particularly concerned with a discussion of the techniques employed and the results found in small-scale model testing. Some important test results are included, together with a list of references where further details are given. Some remarks are also made regarding theoretical methods preferred for analyzing swept-wing structures in Swedish aeronautical establishments.

J. R. Spreiter, USA

2466. Kolom, A. L., Optimum design considerations for aircraft wing structures, *Aero. Engng. Rev.* **12,** 10, 31–41, Oct. 1953.

Three types of wing construction are in general use today: the multirib, in which the compression loads due to wing bending moments are carried in the spar caps; the multistringer, in which the compression loads are carried principally in a sheet-stringer combination; and the multispar, in which the compression loads are carried in the skin.

The multirib construction requires comparatively closely spaced ribs to stabilize the skin and is used to advantage in folding wings and in wings requiring large cutouts. The multistringer construction allows wider rib spacing and is used to advantage where torsional and bending stiffness is required. The multispar with closely spaced spars has few, if any, ribs and is used to advantage in highly loaded thin wings. It produces a very efficient structure in those designs where it can be employed.

For a large number of aircraft being designed today, structural geometry and loading make the use of the multirib and multistringer type of construction more practical. This paper presents the relative weight efficiencies of multirib and multistringer wing compression surfaces and includes curves for the optimum spacing of ribs and stringers for three types of stringers: light-formed "zee," extruded bulb angles, and extruded hat section stringers.

The author concludes that the multistringer construction is generally more efficient than the multirib, since it permits the wider spacing of ribs, the more efficient use of the skin, and the placing of the bending material further from the neutral axis.

The design of the multispar type of wing is also discussed. Curves for optimum spar spacing and optimum skin thickness for this type of construction are presented.

A summary design selection curve for minimum weight structure for a panel whose width is 30 in. for all types of construction covered in this paper and covering a range of loading from 300 to 40,000 lb per in. width of panel is included.

K. Arnstein, USA

2467. **Pittoni, M., Some tests on hinge moments of different ailerons with respect to their lift-increasing power** (in Italian), *Aerotecnica* **33,** 4, 297–302, Aug. 1953.

2468. **Schalin, P. H. B., Determination of optimum dimensions for an aircraft fuselage shell considering special stiffness criteria and minimum weight,** *SAAB Aircr. Co., Linköping, TN* 8, 19 pp., 1952.

Paper considers optimum distribution of material in a fuselage to give minimum weight satisfying given conditions of deflection and slope at the tail. Distribution of radius of gyration is assumed, then methods of calculus of variation are used to find minimum area distribution. A numerical example is given, and conclusion is that, where stiffness is the design criterion, this method gives noticeable weight-saving over scaling-up of area distribution given by strength requirements.

K. H. Griffin, England

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 2408, 2447, 2493, 2496, 2502)

2469. **Onat, E. T., and Prager, W., The influence of axial forces on the collapse loads of frames,** Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 40–42, Apr. 1953.

Paper shows that, if yield curve (M/M_0 vs. N/N_0, where M and N are applied moment and axial load, M_0 and N_0 are limit moment in pure flexure and limit axial load in simple tension) is linear or may be linearized, the location and limit moment of an off-center hinge become independent of the axial load. Under this condition the hinge axis is located a distance cM_0/N_0 from the centroidal axis, where c is the reciprocal of the slope of the "flow vector," i.e., the exterior normal to the yield curve. The collapse load of the frame may be determined consequently as the collapse load of the modified frame with off-center hinges in which the axial loads may be neglected. Authors note that the idealized two-flange member satisfies the above requirement exactly and that the requirement is met approximately by most actual structural sections.

J. E. Goldberg, USA

2470. **Drucker, D. C., Limit analysis of cylindrical shells under axially-symmetric loading,** Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 158–163, Apr. 1953.

Certain concepts from limit theorems which have been developed previously by the author are used to derive expressions for limit loads on cylindrical shells when a ring of pressure is applied, when a band of pressure is applied, and when there is uniform local expansion, all cases being axially symmetric loading.

Yield conditions in terms of force and moment are derived from Tresca's yield criterion of maximum shear stress. In addition to assuming the material is homogeneous and elastic without time effects, one must choose a deformation pattern such that the rate at which the normal force and bending moment do work is equal to or exceeds the internal dissipation (upper bound limit).

Some knowledge is needed of author's previous work to understand the use of limit theorems in this technique.

H. Majors, Jr., USA

2471. **Crawford, S. M., An optical method of observing stress relaxation in transparent solids,** *Proc. phys. Soc. Lond.* (*B*) **66,** part 11, 407B, 954–962, Nov. 1953.

The relaxation of birefringence produced in two organic glasses after they have been sheared in a modified coaxial viscometer has been followed at different temperatures by the use of a photocell. For the low rates of loading used, it has been found that the relaxation of both the glasses can be represented by a single exponential function, which shows that there is one predominant relaxation mechanism. The relaxation times were measured at different temperatures and cover a range from about 20 sec to $^1/_2$ millisec. The viscosity has also been measured over the same temperature range and, from the values of the viscosity and relaxation time at a given temperature, the rigidity modulus of elasticity has been determined. Of the two materials used, one, glycerol sextol phthalate, was more chemically associated than the other, 2′-hydroxy-2:4:4:6:5′-pentamethylflavan. This difference was reflected in the temperature variation of the quantities measured.

From author's summary by C. O. Dohrenwend, USA

2472. **Crossland, B., and Hill, R., On the plastic behaviour of thick tubes under combined torsion and internal pressure,** *J. Mech. Phys. Solids* **2,** 1, 27–38, Oct. 1953.

Limit analysis of engineering structures is based on two simplifying approximations, the practical justification of which is not always evident: strain-hardening is neglected and the equilibrium conditions are satisfied on the undeformed rather than the deformed structure. When these approximations are accepted, the structure is found to yield under constant loads which are not affected by initial internal stresses. Comparatively little experimental information is available regarding the deviation of the actual behavior of elastic-plastic structures from this idealized picture. The present paper contains relevant experimental data obtained from overstraining autofrettaged steel tubes by combined torsion and internal pressure. The general agreement between experiment and theory is found to be excellent.

W. Prager, USA

2473. **Umstätter, H., On creep and relaxation** (in German), *Schweiz. Arch.* **19,** 6, 184–191, June 1953.

After a brief review of stress-strain curves of various materials, author integrates Maxwell's equation for stress relaxation by assuming the strain rate to be a given function of time (power of time). From the result, he draws conclusions on the nonlinearity of stress-strain curves, on creep behavior, and stress relaxation. Finally, results of relaxation measurements on thin steel wires are reported and a very sensitive instrument is described which compares the frequency changes of a steel wire under relaxation with that of a tuning-fork generator; frequency changes of 0.003% can be measured.

Reviewer could not follow the physical meaning of the calculations, as the concepts and assumptions are not clearly stated or consequently applied. For instance, decrease or increase of stress in Eq. (7) has nothing to do with thixotropy but is merely a consequence of the initial conditions.

J. Meixner, Germany

2474. **Gunnert, R., Degree of stress relaxation around 200 300 C** (in French), *Rev. Soudure* **9,** 4, 195–206, 1953.

In order to imitate relaxation of uniaxial residual stresses, test pieces were stressed to yield point at room temperature in a special rigid frame and subsequently heated in furnace to 200–300 C for up to 60 hr. Stresses were calculated assuming Hooke's law and mechanically measuring distances between conical indenta-

tions on side of test piece with a special device allowing considerable accuracy. Uniaxial stresses thus disclosed coincided closely with yield stress at furnace temperature. Certain previous experiments [O. Forsman and K. G. Olsson, "Stress-relieving in weld by heating at comparatively low temperature," State Testing Institute, Stockholm] indicate that similar behavior might be expected also for multiaxial states of stress, e.g., in neighborhood of V-shaped butt weld joining longitudinally two rectangular plates. Author investigates residual stresses on top of such butt weld, using groups of eight indentations, uniformly distributed on a circle of 9-mm diam and measuring the four distances between any two diametrically opposed points in each group. These measurements were then repeated after having relieved the stresses by drilling a ring groove concentrically around each group of indentations. Three of the four distance changes thus obtained suffice together with Mohr's circle and Hooke's law to determine biaxial state of residual stresses. Author finds principal stresses follow same rule as stated above for uniaxial residual stress. Though not stated in paper, the same would be true also for the effective stress! Such presentation of results would seem more natural to the reviewer. F. K. G. Odqvist, Sweden

2475. Hayashi, S., The viscoelasticity of linear polymeric substance, *J. phys. Soc. Japan* **9, 1,** 56–58, Jan.-Feb. 1954.

The viscoelasticity of high polymeric substance is discussed from the standpoint of a molecular theory. The strain of a substance consists of the elongation of polymer and the intermolecular slipping. These two kinds of strain of substance and the elongation of polymer are named the macroscopic elongation and the microscopic elongation, respectively. Supposing the rate of intermolecular slipping obeys Eyring's formula, the relation between the macroscopic elongation-factor λ and the microscopic elongation-factor α is obtained as follows

$$d\lambda/dt = d\alpha/dt + Ab\epsilon\,(\alpha - 1)$$

where A, b, and ϵ are physical constants. Solving this equation we obtain the following results: First, at constant strain the retractive force decays exponentially against time as expected; second, when the velocity of elongation is constant the retractive force shows a maximum against the elongation and decays gradually as elongation goes on. From author's summary

2476. Hill, R., On Inoue's hydrodynamical analogy for the state of stress in a plastic solid, *J. Mech. Phys. Solids* **2,** 2, 110–116, Jan. 1954.

Author discusses analogy considered by Inoue [AMR **6,** Revs. 860, 2584, 2775; *Doshisha Engr. Rev.*, Spec. Paper no. 1].

Inoue had discussed only special cases. Author shows general conditions in which analogy holds. For three-dimensional case, state of stress must be superposition of a uniaxial and hydrostatic stress field; further, yield condition must have certain restrictive singularities. Two-dimensional problems have no such restrictions. Author suggests analogy will be of limited applicability in solving plasticity problems since (1) different types of problems occur in practice, (2) there is no analogy for elastic part of elastic-plastic stress field, and (3) there is no analogy for displacement boundary conditions. P. G. Hodge, Jr., USA

2477. Jenckel, E., Use of models in the study of plastic-elastic behavior (in German), *Kolloid Z.* **134,** 1, 47–64, Dec. 1953.

Author deals with application of Maxwell and Kelvin type model to viscoelastic problems. Combinations of these models are also discussed, as are electrical analogies, the influence of temperature, and the vibration of viscoelastic bodies. Reviewer feels that author should have made reference to the following books which cover the topics in much greater detail: T. Alfrey, "Mechanical behavior of high polymers," Interscience Publ., New York, 1948; A. M. Freudenthal, "The inelastic behavior of engineering materials," John Wiley & Sons, New York, 1950; F. Levi and G. Pizzetti, "Fluage, plasticité, précontrainte," Dunod, Paris, 1951; M. Reiner, "Deformation and flow," H. K. Lewis, London, 1949; C. M. Zener, "Elasticity and anelasticity of metals," Univ. of Chicago Press, 1948. H. Hilton, USA

2478. De Pando, M. V., Disproval of the objections raised to a new theory of plasticity (in Spanish), *Rev. Cienc. apli.* **7,** 34, 402–408, Sept.-Oct. 1953.

Author refutes four objections to his theory of plasticity. He states: (1) His theory is not limited to Poisson's ratio = 2; (2) Stuessi's tests, which agree with author's theory, include loading as well as unloading; (3) in spite of neglecting the square of the strain, his theory is valid over a wide range, which can be increased; (4) his plasticity law agrees as well as desired with von Mises' criterion. C. F. Bonilla, USA

2479. Merrill, E. W., A coaxial cylinder viscometer for the study of fluids under high velocity gradients, *J. Colloid Sci.* **9,** 1, 7–19, Feb. 1954.

Author describes concentric cylinder viscometer designed for measurements on non-Newtonian fluids of high viscosity, at high shear (up to 9000 sec^{-1}). Close approximation to parallel planes is obtained by using very small clearance (0.006 in.) and bottomless shearing surfaces. Data are presented on glucose and glycerol solutions, paint, and varnish. Heat generation in instrument is discussed. I. M. Krieger, USA

Failure, Mechanics of Solid State

2480. McGuigan, M. J., Jr., Bryan, D. F., and Whaley, R. E., Fatigue investigation of full-scale transport-airplane wings. Summary of constant-amplitude tests through 1953, *NACA TN* 3190, 45 pp., Mar. 1954.

Report on the fatigue testing of eight full-scale C-46 wings under four different alternating load levels, all of which had a mean load of 1g. In addition to determining the effect of various stress concentration regions on fatigue failure, the propagation of all fatigue cracks was studied and the effect of fatigue damage on frequency was determined. In the latter, it was found that very little effect on natural frequency occurred even for large fatigue cracks and, therefore, a measure of natural frequency would give no indication of fatigue failures. One appendix is of particular interest since it shows that fine copper wires cemented to a structure in a region of anticipated fatigue failure will break and give a warning of incipient fatigue failures as soon as any small crack occurs. E. E. Sechler, USA

2481. Coffin, L. F., Jr., A study of the effects of cyclic thermal stresses on a ductile metal, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-76, 44 pp.

Thermal cycling may produce fatigue failure of equipment in which severe thermal stresses are developed. The effects of such cycling on Type 347 stainless steel, which were investigated with the apparatus described in another paper (see following review), are reported and discussed. Tubular test specimens were subjected to cyclic-temperature changes and unidirectional constraint so that a constant cyclic strain was obtained. Conditions were varied to obtain data on the effects of (a) thermal stress-cycling on

life to failure and strain-hardening for a fixed mean temperature, (b) previous cold work on cycles to failure, (c) mean temperature on thermal stress-cycling, (d) period of cycle on cycles to failure, (e) prior straining on stress-strain characteristics, and (f) stress concentration on fatigue by cyclic thermal stresses.

Discussion of the test results leads to some general conclusions regarding the fatigue process, and a mechanism for the behavior of ductile metals under cyclic loading conditions is postulated.

R. R. Heldenfels, USA

2482. **Coffin, L. F., Jr., and Wesley, R. P., An apparatus for the study of the effects of cyclic thermal stresses on ductile metals,** ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-77, 15 pp.

Equipment in which severe thermal stresses are developed may experience fatigue failures as a result of thermal cycling. An apparatus designed for the investigation of this problem is described; test results are presented in another paper (see preceding review). The apparatus is so arranged that a tubular test specimen is subjected to a one-dimensional constraint and an alternating uniaxial stress is developed by cycling the temperature of the specimen with resistance heating and a coolant gas. Strain-cycling at constant temperature may also be accomplished by heating and cooling the constraining members instead of the specimen. The control equipment provides automatic cycling to failure and permits considerable flexibility in temperature and frequency of the cycles. An advantage of the apparatus is that the specimen is subjected to a simple state of stress so that elastic and inelastic strains can be separated and the effects of stress concentration, prestraining, and strain-hardening can be studied.

R. R. Heldenfels, USA

2483. **Nakamura, H., Fatigue limit of induction-hardened force-fitted shafts** (in Japanese), *Trans. Soc. mech. Engrs. Japan* 18, 75, 64–69, Nov. 1952.

Most fatigue failures of railway electric-car axles and other force-fitted shafts occur in the sections of force-fitted parts. The author tried to strengthen force-fitted shafts by application of high-frequency induction-hardening to the fitted parts and carried out fatigue tests under rotational bending for various specimens. Carbon steel (0.41% C, 0.15% Cr, 0.32% Cu), normalized standard specimens, normalized force-fitted specimens, and induction-hardened force-fitted specimens were used, the diameter of the specimens being 10 mm and 50 mm. The results are as follows: (1) Induction-hardening is quite effective for strengthening sharp-notched parts of axles and force-fitted parts between gears and wheel bosses. Fatigue strength of an induction-hardened axle is about three times that of the normalized one. (2) Scale effect of normalized force-fitted specimens is very remarkable. Ratio of the fatigue strength of 50-mm diam test piece to that of 10-mm diam one is about 0.6. (3) Induction-hardened test specimens show considerable amount of residual compressive stress, which is considered to contribute to the elevation of fatigue strength. These results about the utility of induction-hardening may be developed into application to electric-car axles, armature shafts, pinions, springs, and so on.

T. Udoguchi, Japan

2484. **Nakamura, H., Mizuma, K., and Funaki, E., Some results of fatigue tests on induction-hardened specimens** (in Japanese), *Trans. Soc. mech. Engrs. Japan* **18,** 75, 70–75, Nov. 1952.

Fatigue tests under rotational bending are carried out for plain and notched specimens which are normalized or induction-hardened locally or totally. The results of tests are summarized as follows: (1) In locally induction-hardened specimens, the fatigue strength of the transitional zone between hardened and nonhardened parts is never lower than that of the mother material. (2) In the test pieces with key-way, the fatigue strength of normalized carbon steel is 13 kg/mm² and increases to 30 kg/mm² in the surface-hardened specimens. (3) Fatigue limits of plain specimens are 29 kg/mm² for normalized 0.4% carbon steel and 66 kg/mm² for quenched and tempered Cr-Mn-Mo steel. The corresponding fatigue strength of V-notched specimens is 10.5 kg/mm² and 17 kg/mm², respectively. On the other hand, the fatigue strength of induction-hardened V-notched specimens increases considerably up to about 50 kg/mm². This increase may be ascribed to the presence of residual compressive stress and preservation of toughness in the surface layer of the specimens.

T. Udoguchi, Japan

2485. **Soete, W., The state of stress and brittle fracture,** Symp., "Notch bar testing and its relation to welded constr.," London, Inst. Weld., 19–27, 1953.

Material Test Techniques

(See also Rev. 2489)

2486. **Fukuroi, T., and Shibuya, Y., The measurement of the Young's modulus of metals and alloys by an interferometric method. III,** *Sci. Rep. Res. Inst., Tōhoku Univ.* (*A*) **5,** 5, 405–412, Oct. 1953.

Using equipment described in AMR **4,** Rev. 3556, authors performed experiments to determine Young's modulus of various alloys. Fe-Al alloys in the composition adjacent to Fe_3Al (13.8% aluminum) have a lower modulus in the annealed state than in the quenched state. Authors also report on moduli of annealed Ni-Al, Al-Cu alloys, and German silver. A. Yorgiadis, USA

2487. **Rondeel, J. H., and Kruithof, R., Semi-automatic apparatus for application of sudden loads upon structural components** (in Dutch), *Nat. LuchtLab. Amsterdam Rap.* S.419, 13 pp., 1953.

An apparatus is described for applying sudden loads to structural components. A maximum tensile load of 4000 kg can be applied within 0.02 sec. Lower rates of loading can be obtained by means of orifice plates. Typical loading curves are given.

M. A. Meyer, So. Africa

2488. **Kruse, E., Problems in standardizing hardness testing** (in German), *Schweiz. Arch.* **19,** 10, 295–299, Oct. 1953.

Mechanical Properties of Specific Materials

(See also Revs. 2402, 2475, 2646, 2689, 2720, 2728, 2730)

2489. **Krafft, J. M., Sullivan, A. M., and Tipper, C. F., The effect of static and dynamic loading and temperature on the yield stress of iron and mild steel in compression,** *Proc. roy. Soc. Lond.* (*A*) **221,** 1144, 114–127, 2 plates, Jan. 1954.

Static compression tests on pure iron and mild steel with 0.19% C were made at temperatures of +80 to −195 C. Stress-strain curves were taken in an apparatus in which the specimen and the lower part of the plunger were encircled by the refrigerant, while the lower pressure plate was cooled only at the upper surface. The yield point was determined either by a marked yield point or as a deviation from linearity. The shape of the curves at the

yield point shows that sometimes there has been a multiaxiality of stress distribution in the specimen. Microscopic examination showed slipbands at the surface of the specimen as soon as the stress-strain curve departed from linearity. At lower temperatures, the yield point increased and was more distinctly marked, while Neumann lamellae appeared.

For dynamic compression tests, the specimen was set between two rods (loading and supporting anvil) of the same diameter, but of a twentyfold length. The velocity of loading varied from 10 to 100 fps. Strain gages were fastened at the anvils. The dynamic compression tests were made at temperatures from +100 to −195 C, but no particulars are given about the temperature regulation. The load-time curves, which stand for the stress-strain curves, generally showed a marked yield point, the curves of the pure iron having a remarkable drop of load. The blows produced deformations from 0.02 to 11%.

The dynamic yield point was always higher than the static, at room temperatures their ratio being about 2.5 for the pure iron and the steel. At low temperatures, as soon as Neumann lamellae formed, this ratio decreased. A. Krisch, Germany

2490. Robertson, J. M., Metallurgical aspects of high temperature steam and gas turbine plants, *N. E. Cst. Instn. Engrs. Ship. Trans.* **70,** part 4, 217–252, Feb. 1954.

2491. Pride, R. A., and Anderson, M. S., Experimental investigation of the pure-bending strength of 75S-T6 aluminum-alloy multiweb beams with formed-channel webs, *NACA TN* 3082, 30 pp., Mar. 1954.

Experimental results are presented for the pure-bending strength of 53 multiweb beams of various proportions. The beams were fabricated from 75S-T6 aluminum-alloy sheet material and have channel-type webs which had been cold-formed with bend radii of four times the web thickness. Local and wrinkling modes of buckling were observed prior to failure. All failures occurred with the formation of a trough in the compression skin extending across the web attachment flanges. The stress levels achieved at buckling and failure are discussed in terms of existing theory. Based upon the failure stresses, design charts are presented which permit rapid selection of the most efficient proportions for given values of an appropriate structural index.

From authors' summary

2492. Louat, N., and Hatherley, M., The behaviour of aluminum deformed under alternating stresses, *Proc. phys. Soc. Lond. (B)* **67,** part 3, 411B, 260–261, Mar. 1954.

2493. Schuette, E. H., Effects of plastic flow and work-hardening in the experimental stress analysis of magnesium-alloy parts, *Proc. Soc. exp. Stress Anal.* **11,** 1, 81–96, 1953.

The problem of determining the life of a metal part subjected to cyclic loading is discussed with regard to need of specifying accurately the existing stress-strain relations. Recognition is made of the change of shape of the stress-strain curve as a result of work-hardening, and experimental curves are presented to show that this phenomenon has the effect of increasing, with cyclic loading, the range of stress over which a linear or nearly linear relationship exists. Testing procedure consisted of rotating, at 1800 rpm, machined sandcast bars of Dowmetal H-T4 in a Krouse fatigue machine and obtaining strain data by manual rotation, initially and after a specified number of cycles. The quantitatively stated results—(1) that fully elastic action exists only up to a stress of about 5000 psi, and (2) that only the unloading curve is elastic for stress ranges of 10 to 12,000 psi—are seriously weakened by questionable assumptions, i.e., that static and dynamic strains are equal, that adequate compensation existed for creep, and that the effect of variation in strain rate was negligible. The qualitatively stated result, that the range of accuracy of the elastic-unloading assumption can be substantially increased by cyclic loading, is possibly of significance in that it indicates development of a condition in which the modulus is approaching a constant value. However, author's point regarding determination of actual stress limits, as contrasted to stress range, in relation to stress history is well taken. Author ignores possible effects of aging on the structure of the metal in its metastable condition.

C. C. Osgood, USA

2494. Ghaswala, S. K., Magnesium alloy structures, *Publ. int. Assn. Bridge struct. Engng.* **13,** 95–124, 1953.

Paper gives a brief historical introduction on magnesium alloys, which are the lightest of all structural metals. In view of their very limited applications in structural engineering, the physical and mechanical properties of the alloys are described and compared with the common engineering materials in order to evaluate their intrinsic worth.

An indication is then given of the salient points of design, covering such topics as tension and compression; elastic and plastic bending; and plates and shells. The problems of elastic instability, which assume considerable importance in magnesium alloys, are then discussed and emphasis laid on the various modes of elastic failure.

Paper concludes with a description of the first magnesium-alloy bridge built in Canada and the mode of utilization of these ultra-light alloys in structural engineering. The various aspects requiring further elucidation for achieving a rational form of design are summarized in order to appraise the latent potentialities of magnesium-alloy structures. From author's summary

2495. Dike, K. C., and Long, R. A., Effect of prestraining on recrystallization temperature and mechanical properties of commercial, sintered, wrought molybdenum, *NACA TN* 2973, 25 pp., July 1953.

This report is a rather detailed experimental investigation of the connection between the recrystallization temperature of commercial molybdenum and the amount of prestraining. The recrystallization temperature of molybdenum appears to decrease in some cases with the increase in the percentage of effective swaging and, in other cases, appears to remain almost constant regardless of swaging. Chemical and x-ray diffraction analyses do not seem to show the reasons for this difference. The atmosphere used to determine the recrystallization data had definite effects on the results. Recrystallized molybdenum, regardless of the amount of prior swaging, possessed mechanical properties inferior to as-swaged or stress-relieved metal at room temperature. At 1800 F, the ductility had no apparent relation to the amount of swaging. R. Truell, USA

2496. Rosi, F. D., Mechanism of plastic flow in titanium: Manifestations and dynamics of glide, *J. Metals* **6,** 1, sect. 1, 58–69, Jan. 1954.

The results of experiments on titanium crystals are reported. It is shown that primary slip obeying the Schmid Law occurs on $\{10\bar{1}0\}$ prism planes in $[11\bar{2}0]$ directions. The spacing of the slip bands is shown to be a function of orientation. Unpredicted secondary slip is shown to occur on the second most highly stressed prism plane. Twinning occurs on $\{10\bar{1}2\}$ and $\{11\bar{2}1\}$ pyramid planes and is shown to be related to the crystal orientation. A detailed discussion of kink-band formation and geometry is given. It is reported that kink bands were never observed in crystals which had deformed by twinning or duplex glide. Some

results are given on critical shear stresses, rates of hardening, stress-strain behavior, and plane of fracture.

J. F. W. Bishop, Scotland

2497. **Andrews, L. E., Record of experimental air-entrained concrete 10 to 14 years after construction,** *Highway Research Board Bull.* 70, 11–23, 1953.

Paper reports on performance of 14 concrete test roads in northeastern area, all over 10 years old. Comparative data from studies of the area of slab scaled indicate superiority of air-entrained cements over conventional cements and mixtures of conventional and natural cements. Also, coarse-ground cements did not compare favorably with fine-ground cements with air-entrainment additions. No data are given on such important variables as the W/C ratio, methods of placement, or finishing procedures on the comparative slabs. I. A. Benjamin, USA

2498. **Press, H., Nailed plate girder for timber bridges** (in German), *Bautechnik* **31,** 2, 36–38, Feb. 1954.

Detailed plans are presented for a ten-span emergency highway bridge of 373-ft length. The five parallel 6-ft high nailed plate girders bridge maximum spans of 42 ft.

Since the nailed structure is fully exposed to the elements, it must have been intended to be of a temporary nature. As such, its design should be of particular interest, considering the feasibility of shop fabrication of the many girders. The use of treated lumber and properly threaded nails would, of course, increase the life of the structure to a considerable degree.

E. George Stern, USA

2499. **Masani, N. J., Timber engineering in India,** Quarterly News Bulletin of the Timber Dryers' and Preservers' Association of India, **2,** 5–8, 1954.

The first efforts in the field of structural engineering of the Timber Engineering Branch of the Forest Research Institute of India, Dehra, India, are described. These efforts include standardization of design loads and stresses and design of economical timber structures. The initially executed roof-truss designs are presented. E. George Stern, USA

2500. **Press, H., Nailed built-up lumber trusses** (in German), *Bautechnik* **30,** 7, 202–204, July 1953; Discussion by Wille, p. 374, Dec. 1953.

Sample designs of built-up lumber trusses are presented, with nails in the double shear. In the discussion of this paper, it is well brought out that the spaced boards need to be connected with spacers to eliminate local buckling and excessive secondary stresses. E. George Stern, USA

2501. **Schliekelmann, R. J., Plastics as construction materials in aircraft construction** (in Dutch), *Ingenieur* **66,** 8, L.9–L.15, Feb. 1954.

A survey is given of the types of plastic materials that may be used in aircraft construction. Thermoplastic sheet material offers low production costs for low-strength parts of complicated shape. Plastic foams are very useful as lightweight core material in sandwich constructions. The most important role, however, is played by the Fiberglas reinforced plastics. This family of materials offers possibilities of producing low-cost airfames with good strength-weight ratio. The problems connected with the low elasticity modulus may be overcome by rational construction methods. From author's summary

2502. **Davies, D. M., and McCallion, H., Effect of previous stress-strain history on the dynamic hysteresis loop for rubber in compression,** *Nature* **173,** 4397, 262–263, Feb. 1954.

2503. **Gumbrell, S. M., Mullins, L., and Rivlin, R. S., Departures of the elastic behaviour of rubbers in simple extension from the kinetic theory,** *Trans. Faraday Soc.* **49,** part 12, 1495–1505, Dec. 1953.

It is shown that the equilibrium stress-strain behavior of highly swollen rubber vulcanizates in simple extension agrees with the predictions of the kinetic theory. The departures from these predictions which are found in dry or lightly swollen rubbers have been investigated, and it is shown that they can be described in terms of a single parameter C_2. The magnitude of this parameter is large in dry rubbers and decreases to zero at high degrees of swelling; this decrease occurs linearly with decrease in the volume fraction of rubber. The value of C_2 is found to be independent of the nature of the rubber polymer, of the degree of vulcanization, and of the nature of the swelling liquid. The possible significance of this parameter is discussed in light of these observations.

From authors' summary by R. G. Boiten, Holland

Mechanics of Forming and Cutting

2504. **Parkins, R. N., and Cowan, A., The mechanism of residual-stress formation in sand castings,** *J. Inst. Metals* **82,** 8 pp., 1953/1954.

Experiments were made on cast iron, brass, and Y alloy to determine effect of temperature differences during cooling, phase transformations, and resistance to contraction in the mold. Using Ferranti and rectangular types of frameworks, it was found that residual stresses depended almost entirely on the temperature differences for nonferrous materials. For cast iron, it was found that the stresses from the phase transformation and mold resistance were of the same magnitude as that due to the temperature difference; however, their effect is important only if the temperature difference exists. C. R. Freberg, USA

2505. **Beamer, P. W., and Tingquist, S. C., Evaluation of casting processes,** *Prod. Engng.* **25,** 3, 139–144, Mar. 1954.

2506. **Leone, W. C., and Saibel, E., The friction terms in metal cutting,** *Trans. ASME* **76,** 2, 195–197, Feb. 1954.

Adopting the concept of an internal coefficient of friction for the shear plane in a continuous cutting process, authors derive an expression relating the shear angle, rake angle, and the internal and external coefficients of friction. The internal coefficient of friction is found to be equivalent to the machining constant introduced by Merchant in obtaining his plasticity equation for metal cutting. The coefficients of internal and external friction are found to decrease with increased tool tip temperature, which is of significance since temperature normally has negligible influence on the friction characteristics of ordinary friction sliders. A thought-provoking discussion and authors' closure are appended to the paper. M. C. Shaw, USA

2507. **Krug, C., and Schneider, G., The technical rigidity of machine tools** (in German), *Werkstatt u. Betr.* **87,** 2, 59–65, Feb. 1954.

Authors deal with the suitability and justification of the expression "rigidity" for the behavior of machines with regard to the service life demanded of them. Other expressions used for the same purpose are critically examined. According to the service

demanded of the machines, the authors distinguish between static and dynamic rigidity. From authors' summary

2508. Neumann, F. W., and Siebel, E., Cold pilger rolling of tubes. Test results of investigations on the rolling process (in German), *Stahl u. Eisen* **74,** 3, 133–145, Jan. 1954.

2509. Adams, G. C., How to make plastic draw dies in nine steps, *SAE J.* **61,** 11, 21–25, Nov. 1953.

2510. Papen, G. W., Requirements for large light-metal forgings and extrusions in the aircraft industry, *Trans. ASME* **75,** 8, 1483–1491, Nov. 1953.
See AMR **6,** Rev. 3779.

2511. McCormick, T. F., Large-extrusion-press operation and production problems, *Trans. ASME* **75,** 8, 1525–1533, Nov. 1953.
See AMR **6,** Rev. 3778.

2512. Mueller, J., Increasing drop forging die life, *Steel Processing* **36, 37;** 12, 1, 2, 3; 616–618, 25–27, 79–81, 132–133, Dec. 1950, Jan., Feb., Mar. 1951.

Hydraulics; Cavitation; Transport

(See also Revs. 2376, 2386, 2586, 2612, 2700, 2727)

2513. Kozeny, J., Hydraulics [Hydraulik], Wien, Springer-Verlag, 1953, xi + 588 pp., 544 figs. $21.

Since the last edition of the famous work "Hydraulik" by P. Forchheimer (1930), this is the first handbook of the Austrian school which will prove to be of great value. Its content is extremely broad, the chapters covering: Properties of liquids. Hydrostatics: pressure, floating, stability, surface forms, capillarity. Movement of ideal liquids. One-dimensional motion, streamline theory, steady and unsteady flow. Impulse-momentum principle and its use. Flow in closed conduits with losses, laminar and turbulent flow, local losses; unsteady flow in pressure pipelines, water hammer, fluctuations in surge tanks, Gibson method. Open channels: uniform and nonuniform flow, bends, backwater; unsteady motion. Three-dimensional treatment of the irrotational flow: potential flow, irrotational vortex. Wave motion. Ground water and its movement. General theory of movement of viscous liquids, lubrication. Efflux from orifices. Flow over weirs and spillways. Resistance and drag, motion of a sphere, of air bubbles, air entrainment by water, hydraulic method of soil analysis, ship resistance, bridge piers, and intake racks. Sediment transportation: suspended and bed-load transport. Principles of model investigations, laws of similarity. Review of vectorial calculus.

It is quite impossible to confine such a large variety of subjects into one volume. Author tried to condense many chapters, sometimes quite skillfully. Some problems are discussed in more detail; e.g., ground-water flow (61 pp.), water hammer (36 pp.), surge tanks (24 pp.), wave motion (24 pp.). Author intended this book not only as a text for students, but also as a manual for engineers [often] faced with the new problems. Much attention is called to the studies in natural conditions (model scale 1:1) as well as of laboratory research. The printing is perfect; a few mistakes need to be corrected: Orientation of Fig. 248 is evidently oblique; graphical multiplication by Harlacher on Fig. 234 is erroneously shown as a division! Generally, the book represents well the contemporary development of fluid mechanics in Europe. S. Kolupaila, USA

2514. Tracy, H. J., and Carter, R. W., Backwater effects of open channel constrictions, *Proc. Amer. Soc. civ. Engrs.* **80,** Separ. no. 413, 18 pp., Feb. 1954.

A method of computing the nominal backwater due to open channel constrictions was sought. A practicable solution has been accomplished which is based on an empirical discharge coefficient and a laboratory investigation of the influence of channel roughness. Also investigated as a part of the laboratory tests were effects of channel shape and constriction geometry. The solution involves the computation of water-surface drop through the constriction and the determination of a factor which is the ratio of backwater to water-surface drop. This ratio is shown to be a function of channel roughness, per cent of channel contraction, and constriction geometry. From authors' summary

2515. Collins, R. D., and Lubanska, H., The depression of liquid surfaces by gas jets, *Brit. J. appl. Phys.* **5,** 1, 22–26, Jan. 1954.

A gas jet directed onto a liquid surface causes considerable agitation of the liquid, a fact which is largely responsible for the rapidity of the steel-making reactions in the side-blown converter as compared to the open-hearth furnace. As a start for a laboratory investigation of this effect, the disturbance caused by an air jet playing on a water surface was photographed. The maximum depth of penetration was measured and plotted against the calculated reaction thrust $\rho Q^2/A$ for a range of jet direction, orifice diameter, distance of orifice from water surface, and air velocity. The consistency of the results within the practical limits of experimental error suggested an empirical relationship between the variables for angles between jet and surface above about 25°, and the following equation was derived, expressing penetration as a function of thrust and angle of jet: $P = 53\tau \sin\theta/[x^2\omega + 19(\omega\tau^2)^{1/3}]$. From authors' summary

2516. Fraser, J. P., Three-dimensional study of a jet penetrating a stream at right angles, *J. aero. Sci.* **21,** 1, 59–61, Jan. 1954.

2517. Mongiardini, V., On the applicability of the equation of motion of the accelerating flow of fluid with free surface (in Italian), *G. Gen. civ.* **91,** 11/12, 694–704, Nov./Dec. 1953.

Critical analysis of the different forms given to the equation of varied motion of a linear flow with free surface. In particular, through a study of the characteristic lines of the differential equation, based on a known research of Massé, evidence is given to the possibilities of formation of breakers; in this case, the study of motion is better conducted by momentum equation.
D. Citrini, Italy

2518. Stanitz, J. D., Design of two-dimensional channels with prescribed velocity distributions along the channel walls, *NACA Rep.* 1115, 40 pp., 1953.
Supersedes articles reviewed in AMR **5,** Revs. 1778, 1779.

2519. Blaisdell, F. W., Hydraulic fundamentals of closed conduit spillways, *Proc. Amer. Soc. civ. Engrs.* **79,** Separ. no. 354, 14 pp., Nov. 1953.

2520. Bossen, M. J., The effects produced during the first few hours after placing an object in a river, *Proc. k. Nee Wet.* (*B*) **56,** 4, 392–402, Sept.-Oct. 1953.

On placing a weir in a river, the permanent state of flow will be temporarily changed into a variable one. The translation waves thus created are damped by friction. A calculation based on the

characteristics method has been developed to estimate the moment at which, in the permanent state of flow, the backwater curve will have established itself.

From author's summary by L. Talbot, USA

2521. **Johnson, G. E., The stabilization of soil by the silt injunction method for preventing settlement of hydraulic structures and leakage from canals,** *Proc. Amer. Soc. civ. Engrs.* **79,** Separ. no. 323, 18 pp., Nov. 1953.

Paper presents a method for consolidating loess or other porous soils by pumping a silt slurry into the moist soil.

From author's summary

Incompressible Flow: Laminar; Viscous

(See also Revs. 2380, 2384, 2513, 2515, 2538, 2540, 2544, 2565, 2585, 2609, 2610, 2611, 2612, 2614, 2704, 2705)

2522. **Barat, M., Variations of pressure in a free jet** (in French), *C. R. Acad. Sci. Paris* **238,** 4, 445–447, Jan. 1954.

Radial pressure distributions in the diffusion zone of an air jet (R_e = 400,000) into the atmosphere are recorded. If p is the pressure in the jet and p_0 the atmospheric pressure, the average value found for $p - p_0$ is about $0.04\ \rho U_0^2/2$, where U_0 is the efflux velocity of the air and ρ its density. Maximum depressions seem to occur in the initial surface of the discontinuity zone; small suppressions are present only in the unperturbed central core. Depressions are explained by author as a consequence of the vortex trail generated in the discontinuity zone. Reviewer believes that data supplied should prove important in future research, since investigations in this field are commonly based on the assumption of hydrostatic pressure distribution [AMR **4,** Rev. 2097]. A. Ghetti, Italy

2523. **Chandrasekhar, S., The stability of viscous flow between rotating cylinders in the presence of a radial temperature gradient,** *J. rational Mech. Anal.* **3,** 2, 181–207, Mar. 1954.

Author assumes that the density of the fluid is linearly related to the temperature, but that pressure is independent of both. He employs Taylor's method, making use of Meksyn's principle of the exchange of stabilities, i.e., that in marginal stability the phase angular velocity of small disturbances is zero, and develops a variational principle for solving the characteristic value problem. He concentrates attention on rigid body rotation and obtains stability criteria when (1) there is a uniform distribution of heat sources in the fluid, and (2) when the two cylinders confining the fluid are maintained at constant, different temperatures.

K. Stewartson, USA

2524. **York, J. L., Stubbs, H. E., and Tek, M. R., The mechanism of disintegration of liquid sheets,** *Trans. ASME* **75,** 7, 1279–1286, Oct. 1953.

Authors study conditions at interface between two fluids, such as air and water, moving relative to one another. A disturbance on the surface of the liquid is acted upon by interfacial tension, tending to restore equilibrium, and by aerodynamic forces, tending to increase the magnitude of the disturbance. If the latter prevail, the interface will be unstable. Authors apply the conditions of potential flow to examine the pressures at the interface, and derive expressions for the rate of growth of disturbances on the surface of the liquid. They show how the rate of growth is affected by the wave length of the disturbance, the Weber number, the densities of the fluids, and the thickness of the liquid sheet. They apply the results to predict the conditions for maximum instability in a liquid sheet, leading to its rapid disintegration, and to estimate the size of droplets formed in the spray from a swirl-chamber atomizer. Comparison with photographs of sprays gives qualitative agreement. E. Giffen, England

2525. **Prakash, P., Two-dimensional steady flows superposable on a source, sink or doublet,** *Bull. Calcutta math. Soc.* **45,** 2, 51–54, June 1953.

The new field of investigations opened by Ballabh [*Proc. Benares math. Soc.* **2,** 69–79, 1940] established the conditions for the superposability of incompressible viscous flows. (Two flows are superposable if the vector sum of the two velocities is again the velocity of a flow, i.e., it satisfies the compatibility equation $\text{curl}\ (\bar{v} \times \bar{w}) + \nu\ \text{curl curl}\ \bar{w} = 0$, where $\bar{v}$ is velocity, $\bar{w}$ vorticity, and ν kinematic viscosity.) Paper under review considers two-dimensional steady flows with the condition for superposability: $\text{div}\ (\bar{v}_1\zeta_2) = 0$, and shows with straightforward derivations that only irrotational flows can be superposed on a two-dimensional source, sink, or doublet ($\bar{v}_1$ velocity of first flow, ζ_2 vorticity of second flow).

Reviewer's note: The significance of superimposed rotational flows from the point of view of finding solutions of the Navier-Stokes equation is somewhat reduced if irrotational flows are studied, since the boundary conditions of viscous flows are incompatible with the continuity equation of incompressible potential flows. V. G. Szebehely, USA

2526. **McDowell, E. L., Axial oscillations of a cylinder in a viscous fluid,** Proc. Third Midwestern Conf. Fluid Mech., Univ. of Minn., 631–634, 1953.

An exact solution of the Navier-Stokes equations is given for the case of a viscous, incompressible fluid of infinite extent surrounding a cylinder of infinite length which is performing harmonic oscillations parallel to its axis. The solution for motion of the fluid within the cylinder and between two coaxial cylinders in axial harmonic oscillation is also given. Comparison is made with the motion of fluid adjacent to a plane surface which oscillates in a direction parallel to the surface.

C. L. Coldren, USA

2527. **Keune, F., An approximate method of calculating the subsonic velocity distribution on high-aspect-ratio swept wings of small thickness at zero lift,** *Roy. Inst. Technol., Div. Aero., KTH Aero. TN* 26, 36 pp., 1953.

An approximate method by expansion of the exact potential function in terms of the ratio of maximum chord to semispan is given for the stated problem. The Prandtl-Glauert rule is used for compressibility correction. The latter correction diverges from known results of infinite span as the aspect ratio diminishes, particularly if the thickness distribution is discontinuous at the root. Examples for the approximate method are given which agree with the results, using the exact potential functions.

H. G. Lew, USA

Compressible Flow, Gas Dynamics

(See also Revs. 2380, 2516, 2527, 2536, 2541, 2543, 2545, 2549, 2550, 2551, 2583, 2615, 2662, 2668)

2528. **Brown, W. F., and Thomas, T. Y., Limiting behavior of pressure derivatives behind shocks in supersonic gas flow,** *J. rational Mech. Anal.* **3,** 2, 231–245, Mar. 1954.

Steady plane flow past a curved surface with attached shock is considered. Entropy S and flow inclination ω are used as coordinates behind the shock. Expressions for p_S and p_ω just behind the shock were derived in a previous paper, where p is pres-

sure. Here limiting values of these derivatives are found for $\sigma \rightarrow \infty$, where σ is distance along the shock from the body nose. Approximate formula for surface pressure is suggested: $p(P) = p(Q) + p_S(Q)[S(P)-S(Q)]$, where P is a point on the surface and Q is a point just behind the shock where the flow inclination equals the surface inclination. A. E. Bryson, Jr., USA

2529. Lin, S.-C., Cylindrical shock waves produced by instantaneous energy release, *J. appl. Phys.* **25,** 1, 54–57, Jan. 1954.

Taylor's analysis of the intense spherical explosion has been extended to the cylindrical case. It is found that the radius R of a strong cylindrical shock wave produced by a sudden release of energy E per unit length grows with time t according to the equation $R = S(\gamma)(E/\rho_0)^{1/4}t^{1/2}$, where ρ_0 is the atmospheric density and $S(\gamma)$ is a calculated function of the specific heat ratio γ. For $\gamma = 1.4$, $S(\gamma)$ is found to be approximately unity. For this case, the pressure p_1 behind the shock wave decays with radius R according to the relation $p_1 = 0.216E/R^2$. Applying the results of this analysis to the case of hypersonic flight, it can be shown that the shock envelope behind a meteor or a high-speed missile is approximately a paraboloid given by $R = (D/\rho_0)^{1/4}(x/V)^{1/2}$ where D and V denote the total drag and the velocity of the missile, respectively, and x is the distance behind the missile.

From author's summary by W. Bleakney, USA

2530. Ludloff, H. F., and Friedman, M. B., Mach reflexion of shocks at arbitrary incidence, *J. appl. Phys.* **24,** 9, 1247–1248, Sept. 1953.

2531. Gilbarg, D., and Paolucci, D., The structure of shock waves in the continuum theory of fluids, *J. rational Mech. Anal.* **2,** 4, 617–642, 1953.

This provocative paper challenges the common belief that continuum mechanics cannot describe the structure of any but the weakest shock waves. According to the conventional view, the Navier-Stokes equations fail because they predict thicknesses of only several mean free paths and must be replaced by kinetic theory, which predicts greater thicknesses. The present authors argue, first, that the N-S equations may apply despite the violation of the continuum assumption; that "indeed this type of success is one of the hallmarks of a great theory." Secondly, they point out that most previous comparisons of thickness are misleading because the kinetic theories assume monatomic gases, whereas the continuum solutions were for air (which gives thinner shocks). A comparison for monatomic gases shows considerable overlapping of thicknesses at any Mach number, depending on the particular molecular model taken for the kinetic theory and on the viscosity variation chosen for the continuum. Finally, it is shown that continuum shock thicknesses are increased appreciably by including either of two refinements, positive compression viscosity for polyatomic gases, or a nonlinear variation of viscosity with rate of deformation. Existence of solutions is proved for the first of these.

M. D. Van Dyke, USA

2532. Ludloff, H. F., On aerodynamics of blasts, Advances in appl. Mech. **III,** 109–144, 1953. [Academic Press, Inc., N. Y.]

This is a connected account of recent work, much of it by author and collaborators, on reflection and diffraction of blast waves by corners and curved sections in walls. First, existing theory of diffraction of acoustic waves by a finite wedge is reviewed. Author then describes his own contribution—to find disturbance when plane blast wave moving parallel to a straight wall is diffracted by a locally nonplane portion with small curvature, such as a thin airfoil surface. He solves this problem in physical plane, for shocks of both medium and high strength. For medium shocks, rotation can be ignored throughout and a disturbance velocity potential is determined, using appropriate Possio integral solutions of wave equation. For strong shocks, Lorentz coordinates are used and Possio integrals now define a disturbance pressure. Extension to diffraction by slender bodies of revolution is achieved by use of retarded potentials. Fields are computed in the case of a wedge and a cone, showing good agreement with interferograms. Finally, author considers problem of head-on collision of shock with almost perpendicular wall. After describing Lighthill's work for a plane wall, he outlines generalization for slightly curved wall, using Possio integral solutions. Reviewer considers this generalization of Lighthill's pioneer work on plane walls [AMR **3,** Rev. 2716; **4,** Rev. 2823] to be of great value. Maurice Holt, England

2533. Arnold, G. M., Strong shock wave decay and applications to aeronautical engineering problems, Proc. Third Midwestern Conf. Fluid Mech., Univ. of Minn., 353–366, 1953.

An oblique shock (caused, for instance, by a concave corner in a supersonic flow) and a following expansion region (as may be created by a convex corner) intersect each other. This process causes a continuous decrease of the intensity of the shock and bending.

An exact method of calculating the interaction of shock waves of arbitrarily strong intensity with an expansion fan is outlined, using the characteristics diagram and a modified shock polar diagram. For the numerical treatment of several examples of projecting or setback corners of 1° to 40° deflection and at $M = 2.6$ and $M = 5$, the exact solution was first approximated by neglecting the vortex sheet behind the shock. The design of the network was done either by geometrical construction or, if necessary, by analytical calculation. For large deflection angle at Mach number 5 and the region near the wall, it was found necessary to repeat the calculation with consideration of the contact discontinuity surfaces. The calculated numerical examples were compared with the results of the asymptotic analysis for weak shocks given in the report by R. Hermann. Shock intensity and width of the disturbance were found in good agreement with the theory for dimensionless distances from the wall of approximately above 100. Several applications of the results obtained to engineering problems are outlined, such as the influence of wall irregularities in a supersonic wind tunnel on the quality of the flow.

From author's summary by A. Miele, USA

2534. Hasimoto, Z., On the solution of some boundary-value problems of compressible fluid flow (in Japanese), *Stud. math. Phys., Tokyo* **2,** 141–187, June 1952.

Exact solution of the hodograph equation for the adiabatic gas flow is considered. In the first part, author discusses the number of zeros of the hypergeometric functions appearing in the solution and obtains the asymptotic expressions for the three cases (subsonic, transonic, and supersonic) by means of the method of the steepest descent. In the second part, two cases of discontinuous flow bounded by two semi-infinite plane walls are dealt with and their singularity (limiting line) is discussed. One is the semi-infinite flow along two half straight lines (either parallel or inclined by an arbitrary angle) and a free streamline connecting them. A rather surprising fact shown is that the form of the free streamline remains constant when the Mach number is varied. The other case concerns the free jet issuing from two inclined plane walls. Special consideration is given to the coefficient of vena contracta. Table and graph giving the value of the coefficient as a function of the angle of inclination are presented.

I. Imai, Japan

2535. **Talbot, L., and Oppenheim, A. K., On the propeller discontinuity,** *J. aero. Sci.* **21,** 1, 61–62, Jan. 1954.

The one-dimensional actuator disk concept is extended for the analysis of compressible flow through propellers. The consequences of the discontinuity assumption are studied. An entropy increase through the disk, which has been ascribed previously to blade friction losses, can occur in a frictionless propeller and is inherent in the actuator disk concept.

R. C. Binder, USA

Turbulence, Boundary Layer, etc.

(See also Revs. 2588, 2615, 2622, 2684, 2711, 2712, 2713, 2726)

2536. **Evvard, J. C., Tucker, M., and Burgess, W. C., Jr., Statistical study of transition-point fluctuations in supersonic flow,** *NACA TN* 3100, 32 pp., Mar. 1954.

Tests were made on a 10° cone at a fixed stream Mach number of 3.12, at two different stream turbulence levels, and at varying test-section Reynolds numbers. By means of schlieren observations, a statistical distribution function $G(x)$, proportional to the total number of times transition occurred upstream of a given point x on the cone, was obtained. This function indicated the reduction of width of the transition zone by a lowered stream turbulence. However, the farthest downstream position of an instantaneous transition did not seem to be affected by the turbulence level. The primary effect of changing the Reynolds numbers was to translate rather than to spread out the distribution functions.

Surface-temperature measuring techniques were used to obtain temperature-recovery-factor distribution along the cone. Results agreed qualitatively with above results of the schlieren observations. Neither peak (approximately 0.89) nor fully turbulent (approximately 0.88) recovery factors, however, seemed affected by either turbulence level or Reynolds number. From the measured time-averaged recovery factors, instantaneous recovery-factor distribution was estimated (mathematical details in Appendix by H. Heermann).

Authors believe that results suggest that flow changes sharply from laminar to turbulent but with transition-point location fluctuating with time. M. Morduchow, USA

2537. **Illingworth, C. R., Boundary layer growth on a spinning body,** *Phil. Mag.* (7) **45,** 360, 1–8, Jan. 1954.

The skin frictional force is calculated for a body of revolution in the early stages of a suddenly initiated (and subsequently constant) screw motion about the axis of symmetry. In particular, the effect of spin on the time of separation of the boundary layer of a sphere in such motion is determined.

From author's summary by E. Leimanis, Canada

2538 **Kline, S. J., and Shapiro, A. H., Experimental investigation of the effects of cooling on friction and on boundary-layer transition for low-speed gas-flow at the entry of a tube,** *NACA TN* 3048, 65 pp., Nov. 1953.

Linearized boundary-layer stability theories have been evaluated by other workers to show the effect of heating or cooling on the critical Reynolds number at which the boundary layer of a gas flow past a flat plate becomes unstable. Authors of this paper attempted to check the theoretical predictions by measurements of the flow characteristics near the entrance of a smooth tube. A secondary objective was to measure and correlate the local "apparent friction factor" in the entrance zone of a tube. Although the existing theories of Lees and Van Driest predict large changes due to cooling in the Reynolds number for the onset of instability, the reported tests show no significant change in the transition Reynolds number. Authors attribute lack of confirmation partly to the influence of finite disturbances such as upstream turbulence level (which was found to be about 0.020 near wall of chamber forward of test section), and suggest that a significant effect of cooling might be detected if the disturbance level is reduced to an extent sufficient to give adiabatic transition—Reynolds numbers greater than 2×10^6. An excellent correlation of the apparent friction factor with a simplified theory developed by the authors for laminar entrance flows is found.

It is the opinion of the reviewer that these tests demonstrate that the small disturbance theories for flows without pressure gradients cannot be adequately checked by means which include free-stream disturbances and slight pressure gradient. A correlation of flat-plate transition Reynolds numbers R_x and intensity of free-stream turbulence u' from various sources made by Macovsky and Breslin [*David W. Taylor Mod. Basin Rep.* 726, Fig. 2] shows the sharp dependence of R_x on u', and, in particular, shows that the turbulent intensities which existed in Shubauer's experiments (which strongly support small-disturbance theories) were $0.0003 \leq u' \leq 0.003$. Furthermore, it does not appear to be possible to reduce the free-stream turbulence level to a point sufficient to obtain $R_x > 2.8 \times 10^6$. Reviewer seriously doubts that technical applications can be generally found in which the cleanliness of system or the free-stream turbulence level is sufficient to obtain an important extent of laminar flow.

J. P. Breslin, USA

2539. **Cliett, C. B., Structural comparison of perforated skin surfaces with other means of effecting boundarylayer control by suction,** *Aero. Engng. Rev.* **12,** 9, 46–54, Sept. 1953.

The results of a series of studies to determine the structural feasibility of perforated sheet materials, which could be used as a means of effecting boundary-layer control by suction, are presented. These results include the ultimate tensile and shear strengths of perforated plywoods, the ultimate tensile and shear strengths of perforated 24S-T3 aluminum-alloy sheet, and the flexure-fatigue strength of this perforated aluminum-alloy sheet.

Empirical methods of predicting ultimate failure in tension and shear for these perforated materials have been found. A comparison between predicted results by these empirical equations and actual experiment has been made, and good agreement is shown to exist.

From the structural point of view, a comparison of this means of effecting boundary-layer control by suction is made with other methods and materials previously advocated.

From author's summary

2540. **Spence, D. A., Growth of the turbulent wake close behind an aerofoil at incidence,** *Aero. Res. Counc. Lond. curr. Pap.* 125, 18 pp., May 1952, published 1953.

A re-analysis of measured mean velocity profiles in the wake of an airfoil has disclosed the following empirical properties: (a) Similarity of the half profiles on either side of the wake center (after the cusp of the trailing edge profile has been faired out); (b) variation of the velocity defect at the wake center inversely as the square root of the downstream distance x from a virtual origin of the wake. These properties are applied to derive an approximate procedure for obtaining the shape parameter H as a function of its value at the trailing edge H_T and of x. Application of this semiempirical theory to the case of a Joukowsky airfoil gives a curve for $H(x)$ which follows the trend of the experimental values but differs in magnitude by about 3%.

The purpose of the work is to derive a method of obtaining the variation of the displacement thickness δ^* of the wake in the neighborhood of the trailing edge for use in calculating sectional

characteristics of airfoils. It is indicated that this is to be accomplished by substituting $H(x)$ into the momentum equation for the momentum thickness $\theta(x)$, and then obtaining $\delta^* = \theta H$.
L. Landweber, USA

2541. Low, G. M., Cooling requirements for stability of laminar boundary layer with small pressure gradient at supersonic speeds, *NACA TN* 3103, 16 pp., Mar. 1954.

According to the formulation in *NACA TR* 876 [1947], the ratio of wall to free-stream temperature required in completely stabilizing the laminar boundary layer is determined for several examples with $M \leq 3$ by trial and error. Flows with greater adverse pressure gradient are found to require more cooling. The wall temperature under radiation effect alone is included for comparison. S.-I. Cheng, USA

2542. Tsuji, H., and Hama, F. R., Experiment on the decay of turbulence behind two grids, *J. aero. Sci.* **20,** 12, 848–849, Dec. 1953.

Interesting tests on the intensity of turbulence $\overline{u^2}$ behind two grids—mesh length and rod size: first grid 5 and 1 cm, second grid 1 and 0.2 cm—at various distances between the grids ($x_1 = 50$ up to 450 cm) and a mean velocity of 10 mps. With x the distance behind the second grid (measured up to 5 m) and x_0 a constant chosen as 0.06 m, Lin's formula $\overline{u^2} \sim [(x - x_0)^{-1} + \text{const}]$ is confirmed unless the large-scale turbulence of the first grid is still too strong, i.e., unless the distance between the grids is too small, $x_1 < 150$ cm or 30 mesh lengths. K. Wieghardt, Germany

Aerodynamics of Flight; Wind Forces

(See also Revs. 2465, 2466, 2468, 2563, 2580)

2543. Stivers, L. S., Jr., Effects of subsonic Mach number on the forces and pressure distributions on four NACA 64A-series airfoil sections at angles of attack as high as 28°, *NACA TN* 3162, 145 pp., Mar. 1954.

Besides ample design data, the report presents evidence that the local supersonic pocket over a convex surface may exhibit a region of continuously increasing pressure upstream of the abrupt shock compression and ultimate boundary-layer separation. This abnormal phenomenon is associated with the high curvature at the nose of the airfoil, but it is not clear to the reviewer whether an invisible local separated "bubble" is essential to the the formation of region. M. V. Morkovin, USA

2544. Dannenberg, R. E., A design-study of leading-edge inlets for unswept wings, *NACA TN* 3126, 56 pp., Mar. 1954.

Paper presents a practical method for determining the profile coordinates of a leading-edge inlet in incompressible flow. Thin airfoil theory was used to calculate change in velocity distribution due to a change in inlet profile; results agree with experiment.

Original publication date was 1950; however, footnotes in present report refer to later work by Flügge-Lotz [AMR **5,** Rev. 971] concerning numerical evaluation of the Poisson integral. Paper should be extremely valuable to designers.
H. N. Abramson, USA

2545. Malvestuto, F. S., Jr., Theoretical supersonic force and moment coefficients on a sideslipping vertical- and horizontal-tail combination with subsonic leading edges and supersonic trailing edges, *NACA TN* 3071, 69 pp., Mar. 1954.

The pressure distribution, side force, yawing moment, and rolling moment due to sideslip are computed for horizontal-tail vertical-fin configurations in supersonic flow. The tails consist of a triangular vertical fin attached to a symmetrical triangular horizontal surface, permitting the use of conical flow methods for determining solutions to the linearized supersonic wave equation.

Although extensive charts are presented for easy computation of the sideslip derivatives, no indication is given of how the results may be applied to tail-body combinations which would be encountered more frequently than the idealized configurations which are treated. L. H. Schindel, USA

2546. Eastman, F. S., The importance of crosswind forces attainable from moving systems, *Trend Engng. Univ. Wash.* 6, 1, 10–16, 28, Jan. 1954.

Paper contains a discussion of the forces acting on two wings moving in opposite cross-wind directions. Author then discusses applications on birds, propellers, and novel moving wing systems. He claims that considerable gains can be obtained from the cross-wind forces in the future if the wing systems can be made in the proper way. T. Gullstrand, Sweden

2547. Küchemann, D., and Weber, J., Concerning the flow about ring-shaped cowlings. Part XII. Two new classes of circular cowls, *NACA TM* 1360, 72 pp., Oct. 1953.

Translation from *Zentrale für wissenschaftliches Berichts. der Luftfahrtforsch Untersuch. u. Mitt.* no. 3111, Berlin.

2548. Naylor, D., Busemann coefficients for a supersonic airfoil, *J. aero. Sci.* **20,** 3, 219–220, Mar. 1953.

2549. Ferrari, C., Calculation of the induced velocities of a wing in linearized supersonic flow (in Italian), *Aerotecnica* **33,** 1, 65–68, Feb. 1953.

2550. Woods, L. C., The two-dimensional subsonic flow of an inviscid fluid about an aerofoil of arbitrary shape. Parts I, II, III and IV, *Aero. Res. Counc. Lond. Rep. Mem.* no. 2811, 58 pp., Nov. 1950, published 1953.

An iterative process (polygon method) for calculating the velocity distribution over airfoils is presented. The airfoil is replaced by a series of small arcs on which it is assumed that the product of the radius of curvature and the velocity is constant. The number of arcs selected is governed by the accuracy required in the final results. The velocity distribution over the airfoil at the angle of zero lift is calculated in the (ϕ, ψ)-plane. The velocity distributions at other angles can then be determined directly. The polygon method is extended to the calculation of velocity distributions over symmetrical sections in symmetrical channels and over arbitrary sections in subsonic compressible flow.
G. E. Nitzberg, USA

2551. Rogers, E. W. E., Observations on a thin cambered aerofoil beyond the critical Mach number, *Aero. Res. Counc. Lond. Rep. Mem.* 2432, 16 pp., July 1950, published 1953.

Paper notes that on a 10% thick airfoil section, of pressure critical Mach number 0.68 and tested at high subsonic velocity at 3.7 deg incidence, an extensive region of supersonic velocity existed without a well-defined shock wave or drag rise. Over a Mach number range 0.68 to 0.775, a drag reduction was observed, and from pressure distribution and direct shadow photographs it has been established that over this range the transition point showed considerable rearward movement, recompression was gradual, accompanied by diffuse small amplitude waves. Small adverse gradient in this region did not cause separation. It is presumed that, because of small losses associated with this form of recompression and lower drag due to a rearward transi-

tion, total drag shows reduction. Paper suggests that theoretical approach is difficult and uncertain but potential solution allowing shock-free recompression may exist. Reynolds number effect is significant in shock-wave pattern, but unknown and complex transonic-flow problems cause doubt in accounting for any set of observations. A. F. W. Langford, Australia

2552. **Jacobs, W., Theoretical and experimental investigations of interference effects of delta-wing vertical-tail combinations with yaw,** *Flygtekn. Försökanst. Medd.* no. 49, 34 pp., 1953.

Author's experiments included force and pressure measurements on a delta wing with 70° sweptback leading edge and three different vertical-tail arrangements. The results showed considerable effects, especially pronounced for the rolling moment. Reviewer feels that the theoretical part is rather crude: The vertical tail was replaced by vortexes assumed known from measurement or other sources. Its streamwise-induced velocity on the wing was then determined and served as the perturbation velocity for calculating the interference pressure. It would indeed be surprising if such theory could be of more than qualitative value, as is borne out by author's comparison of the interference pressure on the wing from both theory and experiment. S. F. Shen, USA

2553. **Mazelsky, B., and Drischler, J. A., Numerical determination of indicial lift and moment functions for a two-dimensional sinking and pitching airfoil at Mach numbers 0.5 to 0.6,** *NACA TN* 2739, 37 pp., July 1952.

The indicial lift and moment functions are determined approximately for sinking and pitching motion at Mach numbers M of 0.5 and 0.6. These functions are determined from a knowledge of the existing oscillatory coefficients at the low reduced frequencies and from approximate expressions of these coefficients at the high reduced frequencies.

The beginning portion of the indicial lift function associated with an airfoil penetrating a sharp-edged gust in subsonic flow is evaluated by use of an exact method. By use of an approximate method for determining the remaining portion, the complete indicial gust function is determined for $M = 0.5$, $M = 0.6$, and $M = 0.7$.

All the indicial lift and moment functions are approximated by an exponential series; the coefficients which appear in the exponential approximations for each indicial function are tabulated for $M = 0.5$, $M = 0.6$, and $M = 0.7$.

From authors' summary

2554. **Le Boiteux, H., and Lygrisse, P., Test of a lateral stabilization device on an experimental flying model** (in French), *Tech. aéro.* no. 35, 9–12, Sept.-Oct. 1953.

Aileron control is obtained by a conventional servo system using a rate gyro transmitter in an integrating circuit. A simple 2.3-ft span test model is launched by an airplane at about 1650 ft and 115 kts and recovered by a telecommanded parachute. Time histories are given of rolling velocity, angle of roll, and normal acceleration with and without aileron stabilization, after launching with preset elevator angle followed by sudden elevator deflection.

The stabilization device is shown to be very effective.

T. van Oosterom, Holland

2555. **Stone, R. W., Jr., and Bihrle, W., Jr., Studies of some effects of airplane configuration on the response to longitudinal control in landing approaches,** *J. aero. Sci.* **20,** 8, 555–562, Aug. 1953.

The investigation reported in this paper was undertaken to see whether there are inherent differences in the response of the flight-path angle to control movements between swept-wing airplanes having no horizontal tail and using trailing-edge flaps for longitudinal control and conventional airplanes that are known to have satisfactory response characteristics. Particular emphasis is placed on the final few seconds of the landing approach.

This study shows that the only difference in the short-time response of the flight path between the two types of airplanes is in a time lag in the flight-path angle response of the sweptwing airplanes. This time lag was found to result from two factors: first, a relatively small value of the parameter, $(VC_{L\alpha}/2\mu\bar{c})(V^2Cm_{\delta_e}/2\mu k_y{}^2)\Delta\delta_e$, which is a measure of the effectiveness of the control in changing the flight-path angle and, second, a relatively large value of the parameter $(VC_{L\delta_e}/2\mu c)\Delta\delta_e$ which is a measure of the amount of undesirable change in lift accompanying the control deflection required to change the angle of attack. It had been suspected that the relatively large change in drag with angle of attack, of low-aspect-ratio swept-wing airplanes having no horizontal tails, would be an important factor in the flight-path angle response; but this was found not to be the case for the short time intervals under consideration.

The importance of the differences found in the response characteristics between the two types of airplanes studied can only be evaluated by flight experience. Other factors such as range of vision, control feel, the pilot's reaction to the relatively large nose-up attitudes of the low-aspect-ratio swept-wing airplanes, and psychological influences associated with new type airplanes may be of equal or greater importance.

From authors' summary by R. L. Bisplinghoff, USA

2556. **Baron, J. R., On the use of the neutral point as a stability parameter,** *J. aero. Sci.* **20,** 2, 145–146, Feb. 1953.

2557. **Bird, J. D., Fisher, L. R., and Hubbard, S. M., Some effects of frequency on the contribution of a vertical tail to the free aerodynamic damping of a model oscillating in yaw,** *NACA Rep.* 1130, 17 pp., 1953.

Supersedes article reviewed in AMR **5,** Rev. 3509.

2558. **Miles, J. W., Virtual momentum and slender body theory,** *Quart. J. Mech. appl. Math.* **6,** part 3, 286–289, Sept. 1953.

Author shows that Munk's virtual momentum approach to the calculation of the transverse forces acting on slender pointed bodies like airship hulls can be reconciled with the more rigorous analysis of Ward, which has been extended to unsteady flow by the author himself. To establish the required identity, the dipole fields at infinity are compared and use is made of a method of solution due originally to Lord Rayleigh, who used it in solving a remarkably similar problem in diffraction.

S. Tomotika, Japan

2559. **Gilutin, E. Z., A statistical analysis of icing-flight observations,** *J. aero. Sci.* **20,** 12, p. 856, Dec. 1953.

Icing-flight data were examined statistically, from which an equation was derived correlating temperature with liquid water content and water droplet diameter. Analysis of the errors involved makes feasible the prediction of the temperature at which a given set of icing conditions is most likely to occur.

From author's summary

2560. **Brun, R. J., Gallagher, Helen M., and Vogt, Dorothea E., Impingement of water droplets on NACA 65A004 airfoil and effect of change in airfoil thickness from 12 to 4 percent at 4° angle of attack,** *NACA TN* 3047, 45 pp., Nov. 1953.

2561. Wilson, L. H., and Falk, J. B., Laboratory simulation of aerodynamic heating for transient temperature measurements, *Aero. Engng. Rev.* **12,** 2, 39–41, Feb. 1953.

Authors claim a laboratory method for determination of transient temperature distributions in aerodynamic heating by a simulation process, in which hot oil flows in steady state and at nearly constant temperature by a model which is to be heated. This method is a crude one, since the reviewer believes that it ignores the types of boundary layers in the oil versus those on the missile, and since the heat-transfer coefficient for the oil flowing at steady state is set equal to a "time-wise average of the air convective heat-transfer coefficients throughout the trajectory" for the aerodynamic heating process encountered by a missile in flight. For these reasons, the "results" shown in Fig. 4 are misleading.

J. Kaye, USA

2562. Assadourian, A., and Harper, J. A., Determination of the flying qualities of the Douglas DC-3 airplane, *NACA TN* 3088, 67 pp., Dec. 1953.

Data are presented showing the longitudinal and lateral stability and control characteristics and the stalling behavior of the Douglas DC-3 airplane and the compliance of these flying qualities with the current Air Force-Navy specifications. Typical frequency-response characteristics of the airplane are also presented for those interested in automatic stabilization.

From authors' summary

Aeroelasticity (Flutter, Divergence, etc.)

2563. Gray, W. L., and Schenk, K. M., A method for calculating the subsonic steady-state loading on an airplane with a wing of arbitrary plan form and stiffness, *NACA TN* 3030, 120 pp., Dec. 1953.

Method is based on a modification of the Weissinger *L*-method. Matrixes and their symbolisms are used for determination and application. Included are fuselage interference, store load effects, modifications for tail-boom and tailless configurations. Method is outlined for determining divergence dynamic pressures for swept wings with large external stores and for reducing wind-tunnel data for freedom from model flexibility effects. Compressibility corrections for subcritical Mach numbers are given. Results show lift-curve-slope variation with Mach number and effective sweep angle at several semispan stations.

Authors believe that because of its length the method is better adapted to determination of loads on specific airplanes than to preliminary design studies. F. Keune, Sweden

2564. Spielberg, I. N., and Wasserman, L. S., The mechanics of aeroelasticity, Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 19–28, Apr. 1953.

The following statements summarize opinions of the authors: (1) The mechanical principles involved in aeroelasticity are quite easily comprehended. (2) Classical orthogonality relations are applicable to all aeroelastic phenomena with the exception of those involving unsteady motions such as flutter. (3) The orthogonality relations useful for unsteady motions involve the use of fictitious conjugate modes or coordinates involving deviations from normal modes. (4) The steady-state aeroelastic analysis for straight and swept wings can be handled satisfactorily by routine procedures involving simplification of both aerodynamic and structural phenomena. (5) The simplified numerical procedures for the aeroelastic analyses of straight and sweptback wings do not appear to be applicable to delta wings. (6) Theoretical research is needed for the development of adequate engineering procedures for estimating structural and aerodynamic forces applicable to the aeroelastic analysis of delta and other odd-shaped wings.

In conclusion, it is pointed out that a new era of airplane design has arrived. Aeroelasticity is now of equal if not greater importance in the design of aircraft than structures and aerodynamics. From authors' summary

2565. Wan, C. C., Airforce coefficients for oscillating airfoils with change of camber in two-dimensional incompressible flow, Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 99–104, Apr. 1953.

Aerodynamic coefficients and generalized forces for a Lagrangian-type flutter analysis are presented for the four usual degrees of freedom: (1) uniform displacement of the chord line; (2) rotation of the airfoil about its midchord point; (3) rotation of flap and tab about the flap hinge line; (4) rotation of tab about tab hinge line—to which a fifth degree of freedom is added, viz., parabolic displacement of the wing. This is taken to be zero at the midchord point, while flap and tab remain rigid in chordwise direction and have no deflection relative to the wing.

A. I. van de Vooren, Holland

2566. de Vries, G., Determination of the critical flutter speed using simplified computations (in French), *ONERA NT* no. 16, 72 pp., 1953.

This report describes a method of calculating the critical flutter speed with five degrees of freedom (wing flexure and torsion, control rotation, and twist and tab rotation), knowing the modes of vibration from resonance tests. Graphs of the aerodynamic derivatives are given for a range of frequency parameters, but all the derivatives are restricted to incompressible flow. An empirical correction is given for compressibility effects.

The flutter determinant is expanded for the case of three degrees of freedom in terms of second-order determinants, and typical calculation sheets are set out, incorporating various self-checking devices. The effect of introducing structural damping is discussed briefly.

The main simplifications of the method described are (1) in grouping together certain of the aerodynamic terms and (2) in assuming mean values of certain theoretical expressions. Reviewer doubts whether much is gained in these ways. It must be stated that the theoretical derivation of the equations is not given completely in this report. This is a disadvantage, as the notation used is not well known. A. W. Babister, Scotland

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 2535, 2608, 2642, 2644, 2694, 2723)

2567. McMullen, J. J., and Payne, W. G., Performance of free-piston gas generators, *Trans. ASME* **76,** 1, 1–13, Jan. 1954.

The rapid development now under way of the free-piston gas-generator-turbine power plant is outlined. The original Pascara unit in France and the Cooper-Bessemer and Baldwin-Lima-Hamilton generators being perfected in the United States are described and possible applications are mentioned.

From authors' summary

2568. McMullen, J. J., and Ramsey, R. P., The free-piston type of gas-turbine plant and applications, *Trans. ASME* **76,** 1, 15–29, Jan. 1954.

Paper is intended to set forth the latent possibilities in heavy-duty free-piston machinery. The cycle promises diesel efficiency from a simple low-temperature gas turbine having low first costs.

Many features are described. Cooper-Bessemer has built a test plant and is now investigating its operating characteristics. No conclusions have been announced. Economic evaluations are being made requiring additional field work, which includes an examination of the general acceptance by engineering and operating people who ultimately will decide the actual utility. Detailed cost studies of complete plants, including careful estimates of the machinery, have been made for electric power generation, pipeline pumping, and marine installations.

From authors' summary

2569. **Putz, T. J., The place of the gas turbine in industry,** *Iron Steel Engr.* **30,** 12, 62–66, Dec. 1953.

2570. **Lamb, J., and Duggan, R. M., Operation of a marine gas turbine under sea conditions,** *Trans. Inst. mar. Engrs.* **65,** 12, 277–292, Dec. 1953.

The paper describes in detail the results obtained over a period of two years with the first gas turbine to be used for the propulsion of a merchant ship. From authors' summary

2571. **London, A. L., The free-piston and turbine compound-engine—a cycle analysis,** ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-212, 30 pp.

Author presents an analysis of the free-piston type of turbine compound engine with and without supercharging-intercooling and reheating, and compares performance estimates of the simple system with that of diesel and turbine cycles. Without intercooling and within the range of compressor pressure ratios limited by practicable engine-charge temperatures, the specific fuel consumption is found to be competitive with that of the diesel, although part-load economy characteristic is not as flat. Air rates lie approximately midway between diesel and intercooled gas turbine, and the cycle would appear to relieve the necessity of high turbine-inlet gas temperatures which limit the conventional gas-turbine cycle. P. J. Schneider, USA

2572. **Lee, J. F., The gas turbine as a combustion topping unit,** *Engng. School Bull. N. Carolina St. College* no. 37, 7 pp., Dec. 1953.

2573. **Rieke, K. L., Temperature and gas-analysis surveys in the combustion zone of a gas-fired gas-turbine combustor,** *Trans. ASME* **75,** 7, 1233–1239, Oct. 1953.

See AMR **6,** Rev. 2329.

2574. **Clauser, F. H., Ramjet diffusers at supersonic speeds,** *Jet Propulsion* **24,** 2, 79–84, 94, 112, Mar.-Apr. 1954.

This is a nonmathematical review of the supersonic diffuser based upon a lecture given by the author at a Symposium on Supersonic Aerodynamics in 1945. As such it contains no new concepts and the material discussed appears in several of the more recent compressible-flow texts. The paper presents an excellent discussion of the behavior of the supersonic diffuser during flight, including problems of aerodynamic control, flow instabilities, and diffuser designs for improvement of efficiency.

R. E. Bolz, USA

2575. **Lukasiewicz, J., Supersonic ram-jet performance,** *Aircr. Engng.* **25,** 296, 298–306, Oct. 1953.

Ideal performance is presented and latest published data on design of intakes and performance of combustor and exhaust nozzle are then used to obtain more realistic analysis. Computation of external drag is discussed in order to assess net performance.

J. C. Wisdom, Australia

2576. **Mattioli, E., The propulsion efficiency of rockets** (in Italian), *Aerotecnica* **33,** 4, 270–274, Aug. 1953.

A new definition is proposed for rocket-propulsion efficiency.

From author's summary

2577. **Baxter, A. D., British progress in propulsion since the war. A survey of the development of gas turbines, piston engines and other power plants since 1945,** *Aircr. Engng.* **25,** 295, 250–263, Sept. 1953.

2578. **Keller, A., and Downs, J. E., Effect of exhaust pressure on the economy of condensing turbines,** *Trans. ASME* **76,** 3, 445–451, Apr. 1954.

The purpose of this paper is to provide quick and accurate methods of determining the change in heat rate, nonextraction steam rate, or turbine capability, resulting from changes in the exhaust pressure of condensing turbines. The methods are applicable for turbines from 25,000 kw to the maximum size built by the authors' company. It is believed that these data will be useful to the power-station designer in selecting between alternative turbine designs with different last-stage bucket annulus areas available in the larger ratings, and also helpful in the selection of condenser size. It also will be useful to the operating engineer in determining when condenser maintenance is advisable, for correcting test data to base exhaust pressure for comparison with guarantee or expected information, and for showing the desirability of operation with less than maximum condenser circulating-water pump capacity in cold weather. From authors' summary

2579. **New, W. R., Redding, A. H., Saldin, H. B., and Fentress, K. O., Basic compressor characteristics from tests of a two-stage axial-flow machine,** *Trans. ASME* **76,** 3, 473–481, Apr. 1954.

This paper reports the results of a high-speed test program on a two-stage axial-flow compressor with an easily defined and accurately reproducible blading. Test Mach numbers cover from 0.3 to 0.9, with 0.62 being critical; Reynolds numbers cover from 50,000 to 500,000, with 200,000 to 300,000 being critical.

Attainable pressure ratios per stage and compressor efficiency are shown to depend upon Mach and Reynolds numbers besides blading geometry, Reynolds number effects being more important below the critical Mach number. Three-dimensional diagrams are included for aiding visualization of these relationships, and are drawn for four velocity ratios.

The relationships among the variables covered by these tests are believed to be generally representative of the behavior of the axial-flow compressor stages at subsonic velocities, even though absolute values of efficiencies and loading are not indicative of the best current design standards. A. S. Andes, USA

2580. **Sears, W. R., Some aerodynamic problems of compressors and turbines,** *Inst. Fluid Dynam. appl. Math., Univ. Maryland* no. 30, 24 pp., Nov. 1953.

The notes are based on the excellent work done by the author and some of his collaborators in the fields of aerodynamic interference between moving blade rows, "rotary stall," and allied problems. The three chapters treat: I. Interference between cascade rows in relative motion. II. Progressive rotating stall as a consistent solution of asymmetric flow. III. Airfoil characteristics after stall.

Incompressible, nonviscous flow is treated, though "certain important effects of viscosity are indirectly accounted for." By giving the methods of analyses and the results obtained, the notes represent an important contribution to the field.

T. P. Torda, USA

Flow and Flight Test Techniques

(See also Revs. 2486, 2542, 2554, 2674)

2581. Mahood, R. F., and Littlefield, R., Use of capillary tubing for flow measurement, *Instrum. Automat.* **27,** 3, 460–461, Mar. 1954.

Tests were run to determine the reliability and predictability of the Hagan-Poiseuille law for liquid flow through commercial tubing. The object of this test was twofold—to determine the equation for predicting flow rates in small-bore tubing, and to determine the reliability and practical value of flow measurement with small-bore commercial-grade tubing.

The following conclusions were reached: (1) The linear relationship between pressure drop and flow through a capillary predicted by the Hagan-Poiseuille law holds true for the data found. (2) The flow rate through a capillary may be predicted with reliability by the Hagan-Poiseuille law. (3) Ambient and flowing fluid temperatures are critical and must be held constant for a constant flow rate. (4) Under carefully controlled conditions, commercial small-bore tubing would be suitable for metering flows smaller than 300 cc/min, where a differential-type meter is required. (5) For services where accuracy of flow and pressure drop is not critical (such as continuous low flow to a liquid sample system or for pressure letdown systems), capillary tubing is useful. From authors' summary

2582. Oppenheim, A. K., and Chilton, E. G., Pulsating-flow measurement—a literature survey, ASME Ann. Meet., New York, Dec. 1953, Pap. no. 53—A-157, 17 pp.

Technical publications on the measurement of pulsating flow are reviewed. Fundamental aspects of the subject are stressed and applications of pressure-differential meters are emphasized because of their importance to industry. Problems related to these meters are classified into those concerned with flow through the meter test section, the effect of the flow system on the meter, and the transmission of the signal from meter to recorder. Operation and application to pulsating flow of other meters such as the turbine type and electromagnetic flowmeter, the hot-wire anemometer, and the so-called "true mass-rate flowmeter" also are outlined. A summary of information available in co les and manuals is included.

From authors' summary by J. F. Manildi, USA

2583. Uyeda, R., and Sugiura, Y., A flow-meter in vacuum technique, *J. Phys. Soc. Japan* **8,** 1, 99–103, Jan.-Feb. 1953.

A direct-reading flowmeter for measurement of Q-values in vacuum technique is defined ($Q = PS$ where P is pressure and S volume flow rate). The principle of the meter is to measure the force exerted on a disk placed perpendicular to the flow and supported by a torsion wire. The force on this plate is computed and measured for ranges from Knudsen to Poiseuille flow. The highest available sensitivity is $10^{-3}\mu$ Hg $\times$ liters/sec for 1 mm of scale. High stability and ruggedness are claimed. The application of this meter to measurement of pumping speed, desorped gas rates, vacuum drying, and leak detection are described.

From authors' summary by E. G. Chilton, USA

2584. Gibson, W. E., The automatic sampling of hydrocarbons in direct proportion to the flow, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-148, 5 pp.

The need of an improved means for obtaining composite hydrocarbon samples automatically has been recognized in the chemical and petroleum industry for years. This is especially true for accounting streams or for any stream requiring accurate sample control. Without any reflection upon operating personnel, the taking of such samples manually is unreliable under the best of conditions. The solution in the form of an automatic sampling device is described. From author's summary

2585. Bentley, R. A., Cartwright, J., and Gordon, R. L., A photographic method of observing the approximate size of liquid droplets produced by an atomizer, *Brit. J. appl. Phys.* **4,** 10, p. 316, Oct. 1953.

2586. Kolossvary, B. G., The reflection method of surface tension measurement, *Amer. J. Phys.* **21,** 7, 510–512, Oct. 1953.

Attention is called to a method of measuring surface tension of liquids, originally due to Eötvös, and suitable for advanced laboratory practice. The method is recommended when freedom from contamination is otherwise difficult to achieve and when measurements are desired over a considerable range of temperature. From author's summary

2587. Hall, I. M., Experiments on supersonic flow over flat-nosed circular cylinders at yaw, *Phil. Mag.* (7) **45,** 362, 333–343, Mar. 1954.

The flow pattern around flat-nosed circular cylinders at yaw was investigated by rotating the body about a line in the free-stream direction and taking schlieren photographs at different positions of the body.

It was found that the shape of the bow shock wave was practically unaltered by yaw, except for the nose regions, but the separation bubble at the shoulder was considerably distorted. Even for small angles of yaw there was a region on the suction side of the body where there was no reattachment.

On the lee side of the body there was a wake which was compared with the vortex wake in the two-dimensional flow past a circular cylinder started impulsively from rest. Good qualitative agreement was obtained. For high angles of yaw, shock waves were found springing from the wake.

From author's summary by H. J. Allen, USA

2588. Hunter, P. A., and Johnson, H. I., A flight investigation of the practical problems associated with porous-leading-edge suction, *NACA TN* 3062, 42 pp., Feb. 1954.

This investigation is concerned with the effect of atmospheric dust and rain on the clogging of the porous leading edge, power requirements, and construction details. In the course of the investigation, the extent of porous area was varied to determine the effect on power requirements and maximum lift coefficients.

From authors' summary

2589. Eggers, A. J., Jr., and Nothwang, G. J., The Ames 10-by 14-inch supersonic wind tunnel, *NACA TN* 3095, 43 pp., Jan. 1954.

2590. Pankhurst, R. C., Raymer, W. G., and Devereux, A. N., Wind-tunnel tests of the stalling properties of an 8 per cent thick symmetrical section with nose suction through a porous surface, *Aero. Res. Counc. Lond. Rep. Mem.* 2666, 14 pp., June 1948, published 1953.

Suction tests were conducted at incidences where the high-speed airfoil section with large leading-edge radius would otherwise have stalled. Several extents of porous surface suction and various amounts of suction have been tested. At low values of Reynolds number (0.19–0.58×10^6) it was found that the quantity requirements are remarkably small. It is not yet possible to estimate the power requirements because the best methods

of porous construction are not known. Some information has been obtained on whether rain would render the porous material (sintered bronze) impermeable. Drying out after the rain had ceased took a considerable time. S. I. Wiselius, Holland

2591. **Williams, W. E., Jr., and Maxwell, E., Liquid level indicator for condensed gases at low temperatures,** *Rev. sci. Instrum.* **25, 2,** 111–114, Feb. 1954.

The instrument described is designed to measure, indicate, record, and control the level of liquefied gases inside a closed vessel. It is especially designed for use at low temperatures with liquefied gases such as nitrogen, oxygen, hydrogen, and helium. It operates on a capacitance principle and makes use of the difference in dielectric constants of the liquid and vapor. The sensing element is a cylindrical capacitor whose capacitance is a function of the height of the liquid column. The sensing capacitor is one element of an automatically balanced bridge which both indicates and records the liquid level. An over-all accuracy of $\pm 1.0\%$ has been obtained. The sensitivity is adequate for use where the difference in dielectric constants of the liquid and vapor is 0.05 or greater. The instrument also incorporates a control function and supplies a controlled air pressure to a pneumatically operated valve for maintaining the level at a predetermined point.

From authors' summary

Thermodynamics

(See also Revs. 2503, 2531, 2571, 2573, 2574, 2583, 2619, 2635, 2639, 2659, 2681, 2691)

2592. **Chapman, S., and Cowling, T. G., The mathematical theory of non-uniform gases, 2nd ed.; —Notes added in 1951,** New York, Cambridge Univ. Press, 1953, ix + 431 pp.; 40 pp. $10.50; $1.

In reprinting this authoritative work on the nonequilibrium characteristics of imperfect and dense gases, authors have added a series of ten notes to bring selected topics up to date. Six of these refer to advances in various aspects of diffusion and thermodiffusion. In addition, note A describes the studies of Hirschfelder and DeBoer on the calculation of transport properties using the Lennard-Jones potential; note B describes work of Kohler on volume viscosity; note G, the third-order extension of nonequilibrium states by Grad; and note H, the theories of liquids developed by Born and Green and also by Kirkwood.

N. A. Hall, USA

2593. **Mason, E. A., Transport properties of gases obeying a modified Buckingham (exp-six) potential,** *J. chem. Phys.* **22, 2,** 169–186, Feb. 1954.

Classical collision integrals, needed for prediction of transport properties of low-pressure gases with spherically symmetrical molecules, are tabulated for kT/ϵ from 0 to 200 and $\alpha = 12(1)15$, for intermolecular potential with exponential repulsion, sixth-power attraction, and a cutoff at small distance. ϵ is depth of the potential well and α is related to steepness of repulsion. Second approximation to thermal diffusion ratio and third approximation to diffusion coefficient are obtained. J. Corner, England

2594. **Rice, W. E., and Hirschfelder, J. O., Second virial coefficients of gases obeying a modified Buckingham (exp-six) potential,** *J. chem. Phys.* **22, 2,** 187–192, Feb. 1954.

Tables of classical second virial coefficient for stated intermolecular potential (see preceding review) for kT/ϵ from 0.4 to 400 and for $\alpha = 12(0.5)15$. J. Corner, England

2595. **Sinden, F. W., On the thermodynamics of irreversible processes** (in German) *ZAMP* **5,** 1, 86–88, Jan. 1954.

Conditions on a linear algebraic eigenvalue problem are given, under which there are exactly k-1 changes of sign in the sequence of components of the kth eigenvector. This is analogous to the oscillation theorems of differential equations. A class of difference equations which satisfies these conditions is defined. Finally, a modification of a method of Collatz is given by means of which upper and lower bounds for the kth eigenvalue may be derived from a trial vector having k-1 sign changes in the sequence of its components. This paper is merely a summary of results; no proofs are given. From author's summary

2596. **Kluitenberg, G. A., de Groot, S. R., and Mazur, P., Relativistic thermodynamics of irreversible processes. II. Heat conduction and diffusion; physical part,** *Physica* **19,** 11, 1079–1094, Nov. 1953.

2597. **James, H. M., and Guth, E., Statistical thermodynamics of rubber elasticity,** *J. chem. Phys.* **21,** 6, 1039–1049, June 1953.

Polemic paper in reply to criticism by Wall and Flory [AMR **5,** Rev. 2163] dealing, apart from points of minor interest, with the probability distribution for the extension of a chain molecule. It is supposed to be (approximately) a normal distribution both for a molecule within a network and a free molecule; in the latter case, the expectation of extension is zero. So far, there is no disagreement. For the case of a network, however, Wall and Flory assert that the expectation vanishes and the variance depends on the elastic strain, whereas, according to the authors' theory, the expectation is finite, increasing with increasing strain, and the variance is independent of the strain. These distribution functions lead to different expressions for the entropy and its change in the process of swelling.

The argument of Wall and Flory depends on a plausible but arbitrary postulate, whereas the authors' theory is based on standard procedures of statistical mechanics; contrary to the critics' objections, no anisotropy of the unstressed state is implied. Reviewer therefore regards the authors' theory as being superior, but is aware of its dependence on oversimplified assumptions. R. Eisenschitz, England

2598. **Munster, A., Statistical fluctuations and thermodynamic stability,** *Z. Phys.* **136,** 2, 179–205, 1953.

The relation between thermodynamic potentials and statistical distribution functions is discussed, and it is shown that strong fluctuations occur under the same conditions as thermodynamic instability leading to phase transitions.

P. Kriezis, Greece

2599. **Holtan, H., Jr., Mazur, P., and de Groot, S. R., On the theory of thermocouples and thermocells,** *Physica* **19,** 11, 1109–1118, Nov. 1953.

The principles of linear irreversible thermodynamics are applied to derive a general expression for the thermochemical electrical potential of a general system in terms of the material electrical transference ratios t_k and the heats of transfer Q_k^*. The resulting homogeneous potential is

$$\nabla \varphi = -\sum_{k=1}^{n} (t_k/e_k)\left[Q_k^* \nabla T/T + \sum_{j=1}^{n-1} (\partial \mu_k/\partial c_j)\nabla c_j\right]$$

This is combined with the heterogeneous potential arising at a material interface to give a general equation for the over-all potential of pure thermocells. The heterogeneous potential is de-

pendent on the entropies of transfer and the electrochemical affinity of the interacting adjacent phases.

N. A. Hall, USA

2600. Dauphinee, T. M., MacDonald, D. K. C., and Preston-Thomas, H., A new semi-automatic apparatus for measurement of specific heats and the specific heat of sodium between 55 and 315° K, *Proc. roy. Soc. Lond.* (*A*) **221,** 1145, 267–276, Jan. 1954.

Equipment measures specific heat by determining rate of temperature rise of small cylindrical sample resulting from a set continuous heat input. Automatic equipment records time, temperature, and power input, and controls power input to maintain three concentric adiabatic shields at temperature extremely close to that of sample. Entire system is placed in an outer Dewar vessel filled with liquid refrigerant.

Sample was formed by pouring molten metal into calorimeter, 1.4-cm diam, 5 cm. long, made of copper 0.008 cm thick and covered on outside with baked varnish. Space above metal is filled with helium, which serves to fill possible gap between sodium (or other test metal) and copper cylinder. Heating coil was formed on outside of cylinder by varnished copper windings, 20 m long of 46 B & S gage; windings also serve as resistance thermometer.

Specific heat of sodium was studied between 55 and 315 °K. Small anomaly, showing hysteresis of $^1/_2{}^{C}_{e}$, was observed at 200 K.

Apparatus is suitable for solids having melting point sufficiently low to permit casting without damage to copper or baked varnish.

D. Aronson, USA

2601. Hirone, T., Maeda, S., Tsubokawa, I., and Tsuya, N., A method of automatic measurement of specific heat, *Sci. Rep. Res. Inst., Tōhoku Univ.* (*A*) **5,** 6, 513–519, Dec. 1953.

An automatic recording apparatus for measuring specific heat of alloys and compounds was constructed. The specific heat could be computed from the recorded chart of the electric current of the feedback circuits for controlling the energy supply, together with the rate of temperature rise of the sample under test. This apparatus has been used effectively for thermal analysis of various kinds of ferromagnetic compounds and binary superlattice alloys. From authors' summary

2602. Leibfried, G., and Brenig, W., On the specific heat of solids (in German), *Z. Phys.* **134,** 4, 451–468, 1953.

In order to calculate the specific heat, the spectrum of the lattice oscillations is approached by a combination of the Debye and Einstein terms. The characteristic constants of this spectrum can be determined from the lattice theory. The model describes the bindings in metallic lattices by springs (central forces) and considers the compressibility of electron gases (volume forces). The atomistic parameters of this model are determined from the elastic constants. Consideration of the volume forces makes it possible to also explain deviations from the Cauchy relations. The calculated specific heat is compared with the exact calculation of the lattice and with the experiment. Both are in agreement. The description of the anomaly of the specific heat in alkalies is quantitatively correct.

From authors' summary by J. N. Aguirre, Argentina

2603. Le Fevre, E. J., A preliminary note on the correlation of the viscosities of gases and other fluids, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-192, 8 pp.

Author uses the law of corresponding states to obtain a universal relationship between the viscosity η and the critical temperature T_c and density ρ_c of a particular gas. From dimensional analysis, the following dimensionless function E, which relates viscosity to the critical properties, is obtained

$$E = \eta(P_c k^2 T_c^2 \rho_c^3)^{-1/6}$$

where k is Boltzmann's constant. It is assumed with theoretical justification that since the densities of gases are low, E is a function only of the reduced temperature $T_r = T/T_c$.

Based on further theoretical considerations, a correlation is derived in which a plot of the logarithm to base 10 of $(T_r)^{1/2}/E$ vs. the logarithm to base 10 of T_r is valid for most gases. Gases whose viscosities are known and which were tested and which fitted this single curve to within about 5% were: Air, argon, methane, ethane, propane, carbon monoxide, carbon dioxide, methyl chloride, chlorine, water, nitrogen, ammonia, neon, oxygen, and sulfur dioxide. Data for hydrogen, helium, mercury, and nitric oxide had a larger deviation from this single curve, and the basis for this behavior is explained. Several theoretical expressions for viscosity based on different physical models are discussed. D. M. Mason, USA

2604. de Boer, J., Theories of the liquid state, *Proc. roy. Soc. Lond.* (*A*) **215,** 1120, 4–29, Nov. 1952.

A critical discussion is given of the various theories of the liquid state, which give an explanation of the liquid properties in terms of the intermolecular forces. From author's summary

2605. Greenwood, N. N., and Martin, R. A., Discontinuities in the physical properties of supercooled liquids, *Proc. roy. Soc. Lond.* (*A*) **215,** 1120, 46–65, Nov. 1952.

The viscosity, electrical conductivity, and density of several liquids have been measured over a range of temperatures both above and below the melting point. The results confirm that the activation energy of viscous flow is greater in the supercooled state than in the normal liquid, the slope of the log η, $1/T$ graphs increasing by about 10% on passing into the supercooled region. In the series of liquids formed by coordinating boron trifluoride to acetic acid and its methyl, ethyl, n-propyl and n-butyl esters, the effect increases with the chain length of the alkyl radical. A similar discontinuity in the log κ, $1/T$ curves indicates that the activation energy for ionic migration is also greater in the supercooled than in the normal state. Although this discontinuity in electrical conductivity has not been noted previously, it is shown to be implied in the numerical results of earlier authors. In contradistinction to viscosity and electrical conductivity, the density varies linearly with temperature over the whole range. These results are discussed in relation to the published data on the other physical properties of supercooled liquids.

From authors' summary

Heat and Mass Transfer

(See also Revs. 2376, 2409, 2411, 2523, 2561, 2593, 2639, 2672, 2676, 2677, 2678)

2606. Rizika, J. W., Thermal lags in flowing systems containing heat capacitors, *Trans. ASME* **76,** 3, 411–420, Apr. 1954.

Equations for computing the thermal lag in parallel flow and counterflow heat exchangers for a step-function temperature input are obtained by the Laplace transform. The physical properties and the heat-transfer coefficients are considered constant, and axial conduction in the wall but not in the fluids is included.

The limiting case of an insulated pipe (only one stream) with a step-function temperature input has been completely worked out and the fluid and wall temperatures plotted dimensionlessly.

For an exponential temperature input plots are given which reduce the solution time. C. F. Bonilla, USA

2607. **Jain, S. C., and Krishnan, Sir K. S., The distribution of temperature along a thin rod electrically heated *in vacuo*,** *Proc. roy. Soc. Lond.* (*A*) **222,** 1149, 167–180, Mar. 1954.

Paper presents solutions for the temperature distributions along a thin rod of finite length, heated electrically, wherein the heat loss to the surroundings takes place by thermal radiation and heat conduction along the rod. The surrounding temperature pertinent to radiant exchange is not necessarily the same as the end temperatures of the rod. The problem as formulated by earlier investigators [see Carslaw and Jaeger, "Heat conduction in solids," Oxford Press, 1947] was solved in series to an adequate degree of approximation made possible by rapidly converging series for the cases of constant properties and for property variations which were linear in temperature.

The temperature distribution along the rod is shown to depend on three parameters: (1) the temperature at the center of the rod, (2) the temperature at the center of an infinite rod heated in the same manner, and (3) a parameter involving the rod cross section, the thermal conductivity, and the surface emissivity. An analytical expression is obtained for the temperature at the center of the rod as a function of the rod length, and graphical results are given for one case where the properties are independent of temperature. Comparison is made of the present solution with earlier, less general solutions. R. M. Drake, Jr., USA

2608. **Ellerbrock, H. H., Jr., Schum, E. F., and Nachtigall, A. J., Use of electric analogs for calculation of temperature distribution of cooled turbine blades,** *NACA TN* 3060, 116 pp., Dec. 1953.

A novel two-dimensional resistance grid was developed using calibrated #24 chromel wire in 1-in. squares spot-welded at each crossing. Boundary layers were represented as usual by rheostats. The temperature distributions in cross sections of three air- or liquid-cooled blades found by the electrical analog checked other methods closely and were obtained more quickly and economically. C. F. Bonilla, USA

2609. **Eckert, E. R. G., and Diaguila, A. J., Convective heat transfer for mixed, free, and forced flow through tubes,** *Trans. ASME* **76,** 4, 497–504, May 1954.

Convective heat transfer is discussed as it is associated with flow through circular tubes under the combined effect of free and forced convection. Buoyancy forces are usually of a smaller order of magnitude than the external forces and can be neglected. Recently, applications have become important in which large free convection forces are present and can change the heat-transfer pattern in high velocity flow. In oil coolers, free-convection currents become of importance due to low forced-flow velocities. In forced flow through rotating parts and cooling of rotating parts, strong free convective flows can be created.

Investigations which were carried out under the conditions that free- and forced flow forces were parallel or opposite in direction are reported. The local heat-transfer coefficients were measured on a short tube $L/D = 5$. The results revealed that the whole flow regime as characterized by its Reynolds and Grashof numbers could be divided into a forced-flow, a free-convection, and a mixed-flow regime. For the parallel conditions, the limit curve between free and mixed flow can be represented by $\mathrm{Re}_x = 8.25\ (\mathrm{Gr} \times \mathrm{Pr})^{0.40}$; and for the limit curve between forced and mixed flow by $\mathrm{Re}_x = 15.0\ (\mathrm{Gr} \times \mathrm{Pr})^{0.40}$. For counterflow, the following represents the limit between free and mixed flow $\mathrm{Re}_x = 18.15\ (\mathrm{Gr} \times \mathrm{Pr})^{0.33}$. The accuracy of the last limit is less than those for parallel flow and can be considered only as tentative. In determining the corresponding counterflow limit for pure forced flow, difficulty was encountered and no equation given. Suitable explanations are given to point out the difficulties in dealing with this case.

Actual heat-transfer coefficients in the forced- and free-flow regime can be calculated with established relations; for the mixed-flow regime they are presented in a series of figures. Results of other investigators have been included to generalize and extend the relations obtained. The analysis by Martinelli and Boelter for the laminar parallel-flow condition has been extended to the laminar counterflow range. I. Glassman, USA

2610. **Marris, A. W., On the Nusselt modulus as a function of friction factor, Reynolds and Prandtl moduli, for heat transfer to a fluid flowing turbulently through a tube of circular section,** *Canad. J. Phys.* **32,** 2, 167–189, Feb. 1954.

Author presents a theoretical development of heat transfer to a fluid flowing turbulently through a circular tube. The assumption is made that the longitudinal gradient is independent of the radial position. Equations are developed in which the Nusselt modulus and the radial temperature distributions are expressed in terms of the Reynolds number, Prandtl number, the friction factor, and the ratio of the eddy diffusivities for heat and momentum. The formulas predict the zero temperature gradient at the tube axis observed experimentally. Means of evaluating the consistency or lack of same of the heat and momentum eddy diffusivity ratio is considered. L. Lapidus, USA

2611. **Marris, A. W., An experimental investigation of the heat transfer to turbulently flowing pressurized air,** *Canad. J. Phys.* **32,** 2, 190–200, Feb. 1954.

Author describes an experimental investigation employing a counterflow heat exchanger. Values of the heat-transfer coefficient, the friction factor, and the Nusselt modulus are evaluated over a large range of Reynolds numbers.

Data compared to von Kármán's theoretical friction-factor equation showed reasonable agreement. No variation in the friction factor with the heat-transfer rate could be detected. For Reynolds numbers less than 0.75×10^5 the values of the product of the Nusselt number and the friction factor agree approximately with a theoretical development by the author, provided the ratio of the eddy diffusivities for heat and momentum is taken as unity. Above a Reynolds number of 0.75×10^5 the Nusselt number-friction factor values were proportional to the heat-transfer rate. L. Lapidus, USA

2612. **Johnson, H. A., Clabaugh, W. J., and Hartnett, J. P., Heat transfer to mercury in turbulent pipe flow,** *Trans. ASME* **76,** 4, 505–511, May 1954.

An investigation of heat transfer to mercury in turbulent pipe flow with Reynolds modulus ranging from 14,000 to 400,000 in a 0.652-in. ID mil l-steel-tube heat exchanger. The results are correlated for the Peclet modulus range from 200 to 10,000 and are 4 to 10% lower than the previously reported values for lead-bismuth and 35 to 40% lower than the Martinelli-Lyon momentum theory. No difference was noted in the heat transfer for upward vs. downward flow or for the use of argon as a replacement for the helium atmosphere. No doubt these results, which are a valuable contribution, will be of interest to those engaged in atomic work. Although this same heat exchanger was used for the molten-lead-bismuth investigation and apparently every precaution was taken to assure accurate results, the effect of flow direction and the problem of wetting may not have been completely investigated. C. C. Eckles, USA

2613. Kays, W. M., Pin-fin heat-exchanger surfaces, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-211, 17 pp.

Summary of performance test data (heat transfer and flow friction) on pin-fin heat-exchanger surfaces. Effectiveness of different design forms is discussed and the possible practical application is evaluated. Pin vibration occurring within the expected range of Strouhal number must be avoided.

H. H. Korst, USA

2614. Herbeck, M., Heat exchange between a heated band and a convective stream (in German), *Z.A.M.M.* **33,** 10/11, 362–382, Oct./Nov. 1953.

The problem of heat transfer from a heated band to a cool stream is considered. The temperature T (reduced form) in the case of shear flow is governed by the differential equation $T_{\xi\xi} + T_{\eta\eta} = \eta T_{\xi}$, ξ and η being, respectively, nondimensional coordinates parallel and perpendicular to the band, lying in the ξ-axis. The solutions were carried out for different boundary conditions: (1) The band is maintained at a certain temperature higher than that of the free stream, and elsewhere on the ξ-axis the temperature is held at the temperature of the free stream; (2) the band is maintained at a certain temperature, and elsewhere on the ξ-axis the temperature falls off exponentially, in both up- and downstream directions, from the temperature of the band to that of the free stream at infinity. Analytical and numerical results are both presented and a comparison with experiments is also made.

Y. H. Kuo, USA

2615. Woolard, H. W., The influence of wedge thermal conductivity upon the surface temperature distribution of a wedge with a laminar boundary layer in supersonic flow, *Cornell aero. Lab. Rep.* no. CAL/CF-1991, 14 pp., Feb. 1953.

The cosine series solution for steady-state heat conduction in a solid wedge is employed in combination with Lighthill's solution [AMR **4,** Rev. 2612] for heat conduction through a laminar boundary layer to obtain expressions for surface temperatures and heat transfer to the wedge. Apparent recovery factors (based on these surface temperatures) are calculated for a 5.71° semivertex angle steel wedge and compared with experiment (turbulent boundary layer). Both theory and experiment show, as would be intuitively anticipated, a decrease in recovery factor (in the neighborhood of 1%) with increasing distance from the leading edge. More than this quasi-confirmation of theory could not be and was not expected, in view of the disagreement between boundary-layer types postulated in the theory (i.e., laminar) and obtained in the experiment (i.e., turbulent).

A. J. Eggers, Jr., USA

2616. Snyder, N. W., A review of thermal-radiation constants, *Trans. ASME* **76,** 4, 537–539, May 1954.

Author makes a case by criticizing the accuracy of the values of the constants in Planck's radiant energy equation published from 1911 to 1930. He suggests new and more accurate constants computed from more recent data compiled by Dumond and Cohen. Just for curiosity, the reviewer picked up a "Handbook of chemistry and physics" published five years ago; the values of the constants given in the handbook differ from those in the paper by less than 0.02%. Reviewer's opinion is that, for engineering applications, one should not worry about such minute discrepancies.

S. Eskinazi, USA

2617. Kreipe, T. F., A new type of radiant tubular heater, *Trans. ASME* **76,** 3, 337–340, Apr. 1954.

The advantages of applying direct radiant heat to both sides of heating coils in tubular furnaces, as compared to the more customary direct application of radiant heat from one side only, are discussed. The operation, construction, and application of a novel radiant-type burner which embodies many desirable features are described. Use of the burner in tubular heaters is discussed and operating data are presented.

From author's summary

2618. Sarjant, R. J., Heat transfer in a continuous reheating furnace, *J. Inst. Fuel* **27,** no. 156, 16–24, Jan. 1954.

Describes heat-transfer studies in a pilot-scale gas-fired experimental furnace similar to industrial furnaces for heating metals. Furnace was fully instrumented, simulating a calorimeter. Thermocouples in walls and hearth, a hearth calorimeter, and a high-velocity gas thermocouple permitted measurement of heat release from the flame and the heat transfer to specific areas of the furnace. Using different furnace charges, author shows that heat transferred to the charge and the maximum temperature attained increased linearly with the amount of fuel fired. Utilization efficiency, expressed as percentage of total heat transferred actually going to the charge, was nearly constant, increasing only 5% over a wide firing range. Furnace efficiency similarly did not vary more than 7% at different firing rates. Data presented show that of all the heat transferred to the charge and lost through the walls, only half could be accounted for by change in the sensible heat of the furnace gases. Author attributes this to reradiation from the burner wall, not satisfactorily measured in this series of tests. Further experimental research is under way to determine if the heat lost by the gases in a given section of the furnace is received by the surface boundaries of that section.

W. T. Reid, USA

2619. Rhodes, J. E., Jr., Radiation pressure against perfect reflectors, *Amer. J. Phys.* **21,** 9, part I, 683–687, Dec. 1953.

The concept of radiation pressure exerted against a reflecting surface by electromagnetic waves and by sound waves in gases is a familiar one. The absence of radiation pressure for sound waves in a linear medium is becoming well known. The equations are somewhat different for the radiation pressure for these two cases where the radiation pressure is not zero. The mechanisms usually called on to explain them (nonlinearity of the equation of state of the gas, acceleration of charges in the reflector by the electromagnetic waves) are widely removed from each other. Consequently, it is not evident on the surface whether radiation pressure is a general property of waves or the capricious result of isolated physical phenomena associated with some waves.

A generalized concept of radiation pressure is here developed and then applied to several kinds of waves: Sound waves in various media, waves on strings and springs, electromagnetic waves. Also, a simple demonstration of radiation pressure (for waves in a ripple tray) is described.

From author's summary

2620. Yagi, S., and Kunii, D., Proposed theory of radiant heat transfer in the furnace and its application, *Jap. Sci. Review* 2, 4, 397–408, Sept. 1952.

Authors develop equations for radiant heat interchange in an enclosure containing a hot surface, a cold surface, a black surface, one refractory of uniform temperature, and a gas mass of uniform temperature and composition. Method used is to trace various beams of radiation and their multiple reflections through the furnace to arrive at general equations; then to simplify equations for certain industrially important cases containing only some of the above surfaces, such as an electric furnace, Lancashire boiler, etc.

Reviewer believes results are correct though not general

enough. Readers are referred to a more general treatment, covering an enclosure containing a uniform gas mass surrounded by any number of heat-receiving or refractory surfaces, developed by Hottel [10.74 "Furnace design notes," M.I.T., 1951; McAdams, "Heat transmission," 3rd ed., 1954, chap. IV by H.C. Hottel].

E. Cohen, Holland

2621. **Berman, K., Erosion by melting and evaporation,** *Trans. ASME* **76,** 3, 397–405, Apr. 1954.

This work represents an investigation of the erosion of solid bodies placed in an air stream. The test specimens were formed into cylindrical and conical shapes. Ice, acetophenone, and paradichlorobenzene were used as the materials for the solid models. It was possible to correlate the rate of erosion as a function of the Reynolds number. From author's summary

2622. **Clark, J. A., and Rohsenow, W. M., Local boiling heat transfer to water at low Reynolds numbers and high pressures,** *Trans. ASME* **76,** 4, 553–561, May 1954.

Local surface coefficients of heat transfer and maximum heat-flux density are presented for degassed distilled water flowing upward in a vertical L-nickel tube under the following conditions: Mass velocities in the range 2.6 to 73 lb_m/ft^2 sec (or inlet velocities in the range 0.05 to 1.4 fps), absolute pressures up to 2000 psia, and liquid subcooling between 0 to 300 F. The effects of natural convection on the nonboiling heat-transfer process were found to be significant, causing the transition from laminar to turbulent flow at the surface to occur at length Reynolds number in the range 60,000–100,000. Emphasis is placed on data in the region of surface boiling. The test section dimensions were 0.180 in. ID and 9.4 in. long.

From authors' summary by C. L. Coldren, USA

2623. **Crico, A., Simultaneous heat and mass transfer during strongly exothermic absorption of pure gases** (in French), *Chim. et Industr.* **70,** 6, 1086–1092, Dec. 1953.

Paper presents the method of calculating the surface area and cooling water requirements for absorbing a pure gas in a flowing film of liquid. The cooling water is required to remove the heat of absorption so that the process may be carried out isothermally. Equations are derived which are applicable to any pure gas in counterflow with an absorbent. An example is provided wherein the gas is ammonia and the liquid is water.

There is a brief discussion of the similarity between heat and mass transfer in the type of exchangers considered.

S. Zivi, USA

2624. **Traupel, W., The law of similarity in film condensation,** *Sulzer tech. Rev.* no. 3, 27–31, 1953.

A presentation of the sequence of calculations for the design of a condenser based on the assumptions of film condensation and negligible resistance to heat conduction. The Nusselt formula for the film coefficient is used in dimensionless form.

W. L. Sibbitt, USA

2625. **Gregorig, R., Film condensation on uneven surfaces with regard to surface tension** (in German), *ZAMP* **5,** 1, 36–49, 1953.

Paper treats film condensation on the outside of vertical tubes which have rippled surfaces with the grooves parallel to the tube axis. Both laminar and turbulent flow of the condensate are considered.

Surface tension of the liquid-vapor interface produces very large pressure gradients in the film because of the different curvatures of the condensate surface. The effect of the surface tension can amount to a large multiple (a few powers of ten) of the effect of gravitational forces. Large gradients in pressure produce very thin condensate films at the peaks of the rippled surfaces and result in high heat-transfer coefficients in this region.

Heat-transfer coefficients are calculated by finite difference calculus for a particular geometry and the results confirmed by tests. The results are also shown in the form of dimensionless numbers. W. M. Rohsenow, USA

2626. **Hirano, F., and Nishikawa, K., Theoretical investigation on heat transfer by nucleate boiling** (in Japanese), *Trans. Soc. mech. Engrs. Japan* **18,** 72, 23–26, Aug. 1952.

Authors assume that the main driving force of convection at the stage of nucleate boiling is the change of apparent density due to rising bubbles, and introduce an equivalent Grashof number due to this effect, in place of the usual Grashof number, into the heat-transfer formula for free convection. They then show that Nusselt number is proportional to $n^{1/4}$, where n is the number of nuclei of steam bubbles generated on the horizontal heating surface. This fact was previously found experimentally by the same authors. As one of the factors which determine n, the effect of contamination of the surface is discussed.

H. Tamaki, Japan

2627. **Eberle, F., Ely, F. G., and Dillon, J. A., Experimental superheater for steam at 2000 psi and 1250 F—Progress report after 12,000 hours of operation,** *Trans. ASME* **76,** 4, 665–675, May 1954.

2628. **Armacost, W. H., The controlled-circulation boiler,** ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-91, 21 pp.

From the standpoint of circulation there are two general types of boilers in operation in this country. These are natural-circulation based on the conventional "thermal circulation head," and controlled-circulation based on the use of a pump to distribute and circulate the water through the heat-absorption areas. The author's company supplies both types, having pioneered in the design and development of natural-circulation as well as controlled-circulation boilers. With the trend toward larger high-pressure units, industry is directing more and more attention to the controlled-circulation type. Therefore, it appears desirable to summarize the information regarding these boilers. This paper deals largely with (a) the development of these boilers, (b) presently preferred designs, (c) operating features, results, and characteristics, and (d) brief reference to installations in this country. From author's summary

2629. **Monteith, J. L., Error and accuracy in thermocouple psychrometry,** *Proc. phys. Soc. Lond.* (*B*) **67,** part 3, 411B, 217–226, Mar. 1954.

Paper discusses the main sources of error in the determination of vapor pressure with a thermocouple psychrometer. The predictions of theory and the results of experiment lead to no general agreement on the value of the constant in the classical psychrometer equation. A new derivation of the equation suggests a reduction of the commonly accepted value by a power of the ratio of diffusion coefficients for heat and water vapor. An expression is derived for the radiation error due to the difference of temperature between the wet bulb and its surroundings. Conduction of heat along the thermocouple wires and extraneous radiation produce errors for which an expression is derived for a particular thermocouple model. Finally, wet-bulb temperature errors are related to the corresponding vapor pressure errors.

From author's summary by M. J. Goglia, USA

Combustion

(See also Revs. 2572, 2573, 2574, 2620, 2679)

2630. Dollé, L., Investigation of inflammability limits of vapors of solid compounds (in French), *Publ. sci. tech. Min. Air, Paris* no. 287, 86 pp., 1953.

An experimental method is described which permits the preparation of mixtures of the vapors of low volatility compounds with air at various initial temperatures and pressures. The inflammability limits of naphthalene and phthalic anhydride are reported as a function of temperature and pressure. Ignition was by repeated sparks; tube diameter 25 mm, horizontal propagation. Naphthalene has a range of inflammability at atmospheric pressure of 3.2 to 32.3 gr per 100 gr of dry air at 350 C and 4.7 to 26.2 at 125 C. The lower limit is 5.4 at 85 C. The low-pressure limit at 350 C is 80 mm and at 150 C is 105 mm. Phthalic anhydride has a lower limit of 4.1 at 450 C and 8.8 at 150 C. It has an inflammability range of 4.4 to 57.0 at 400 C and 7.2 to 40.0 at 200 C. The low-pressure limit at 400 C is 70 mm and at 200 C is 80 mm. Three-dimensional graphs of all the data are shown. The lower-limit results are in reasonable agreement with Bechert's theory but the upper limit, particularly at low pressures, is not adequately described. Other theories are reviewed.

M. Gerstein, USA

2631. Prout, W. E., and Anderson, R. C., Flame propagation in the self-combustion of acetylene, *Fuel* **33,** 2, 125–133, Apr. 1954.

Results of a series of experiments on flame propagation in a system involving only hydrocarbon reagent, i.e., in acetylene in the absence of oxygen, are summarized. Moving pictures were used to record the motion of the flames in cylindrical glass tubes and the pressure changes during flame propagation. The effects of variations in initial pressure and temperature, tube diameter, etc., have been determined. The results indicate that polymerization of unreacted acetylene occurs readily as a secondary reaction after flame propagation. They also indicate that combination or polymerization steps are important in the reactions involved in the flame propagation, although the over-all reaction must follow a chain mechanism. From authors' summary

2632. Egerton, Sir Alfred, and Lefebvre, A. H., Flame propagation: the effect of pressure variation on burning velocities, *Proc. roy. Soc. Lond.* (*A*) 222, 1149, 206–223, 4 plates, Mar. 1954.

The accurate study of the rate of flame propagation over as wide a range as possible is important to determine the form of the velocity vs. pressure relationship. In this work, velocity measurements were made using the tube method; the actual flame area was obtained from schlieren photographs of the combustion front. The gases used were methane, propane, ethylene, and propylene-air mixtures at constant pressures from 0.5 to 9 atm. For methane, $V_b \propto p^{-0.5}$; for the others, $V_b \propto p^{-0.3}$, but the pressure exponent varies with mixture composition; richer mixtures are less affected by pressure.

Conditions leading to vibration and turbulence in the flame front were also examined, and a critical discussion of the shortcomings of the tube method without examination of flame shape is given. T. L. Cottrell, Scotland

2633. Kirtley, J. G., and Lewis, A., Flame stability studies of different vaporized fuels under non-homogeneous mixing conditions in a small scale combustion tube, *Fuel* **33,** 1, 5–19, Jan. 1954.

Extension of the work of Wakelin, Heron, and Baldwin uses the same quartz combustion chamber, but with a nozzle having a single axial hole. Twelve fuels were tested, including n-hexane, isobutane, triptane, acetylene, acetone, xylol, cumene. Isooctane was tested with amyl nitrite, di-tert.-butyl peroxide, and tetraethyl lead.

Flame characteristics, stability limits, and effects of fuel and air-inlet temperatures were studied. Nitrogen mixed with some fuels to keep comparable flow conditions makes different fuels difficult to compare. Those having higher combustion rates gave more uniform combustion. Additives showed no appreciable effect.

Eddies and low-velocity regions were obviously important in maintaining combustion. Stability limits were distinctly wider than for homogeneous mixtures.

R. C. Anderson, USA

2634. Spalding, D. B., Theoretical aspects of flame stabilization, *Aircr. Engng.* **25,** 295, 264–268, 276; Sept. 1953.

An analysis of the propagation of flames is made with the presumption that the controlling mechanism is thermal conduction. The heat-release rate by chemical reaction is according to the Arhennius reaction rate relationship. Application is made on a qualitative basis to a number of unsteady-state flame phenomena, including the initial development of a steadily propagating flame, extinction of a flame, propagation from pilot flames, and flame stabilization in turbulent flow fields. The unsteady-state solutions are dealt with graphically by the method of Schmidt plotting.

Results of the analysis for highly turbulent flow fields in the vicinity of bluff bodies show that the extinction velocity should be proportional to (1) the linear dimension of the bluff body, (2) the absolute pressure, and (3) the square of laminar flame velocity in the same media. E. S. Starkman, USA

2635. Macioce, E., Thermodynamic charts of the products of combustion (in Italian), *Aerotecnica* **33,** 4, 288–290, Aug. 1953.

Two thermodynamic charts, introduced by R. L. Hershey, J. E. Eberhadt, and H. C. Hottel and further modified by L. Crocco, are examined. They are useful for a rational analysis of the actual phenomena which occur during the internal-combustion process.

From author's summary

2636. Véron, M., New contributions to graphical method of combustion control (in French), *Bull. tech. Soc. fr. Constructions,* Babcock & Wilcox no. 25, 78 pp., Oct. 1952; Hermann & Cie., Paris.

Two types of combustion charts are described in detail, one being the polar diagram of Véron and Dumez, and the other being the alignment chart of Paignant. With the aid of either of these charts the interpretation of results of gas analysis, the control of air for combustion, and the calculation of heat balance are greatly facilitated. T. Y. Toong, USA

2637. Luft, N. W., and Cohen, L., Flat flames of ammonia in air, *J. chem. Phys.* **22,** 2, p. 348, Feb. 1954.

2638. Cude, A. L., The length of oil and gas flames, *J. Iron Steel Inst. Lond.* **175,** part 3, 304–312, Nov. 1953.

The length of turbulent unconfined vertical flames L may be correlated with the fuel mass flow rate w and the momentum flux G through the burner nozzle by the equation $L = kwG^{-1/2}$, where k is a dimensional constant depending on the fuel, the burner, and the manner and amount of primary and secondary air addition. The author determined values of k for town gas (city gas)

and for gas oil. A variety of burners were used, and the primary and secondary air were injected either in the direction of the fuel flow or with a tangential velocity component. It is found that the above equation holds quite well except for very long flames which are shortened by buoyance effects, flames confined in chambers less than $^1/_3$ of the free-flame length in diameter, and diffusion flames. Additional tests show that the proximity of a similar flame less than $^3/_4$ of the flame diameter away tends to lengthen the flame, and that the impingement of a flame on a flat surface at an oblique angle lengthens the flame, unless the impingement point is within $^1/_4$ of the free-flame length from the burner, in which case the flame is shortened.

A. W. Gessner, USA

2639. **Murata, T., On diffusion theory of methane combustion,** *Jap. Sci. Rev.* **2**, 4, 421–427, Sept. 1952.

Author has introduced a differential equation of concentration of chain carriers in gaseous reaction and derived the general solution of equation in the case of unsteady state for 9% CH_4-air mixture. The concentration of chain carriers in the initial reaction region decreases first by diffusion and afterward increases rapidly by chain-branching reaction. The inhibiting action of the inhibitor contained in permissible coal-mine explosives should be effective in chain-decreasing duration in order to prevent the transformation to detonation from combustion of CH_4-air. This duration of decreasing of chain concentration may be called shrinkage time.

If the pressure of CH_4-air mixture surrounding a coal-mine explosive is 10 atm, the shrinkage time is 4×10^{-6} sec. The formulas of rate of stationary combustion of a gas can also be deduced from the author's general solution.

From author's summary

2640. **Simon, D. M., and Wong, E. L., An evaluation of the soap-bubble method for burning velocity measurements using ethylene-oxygen-nitrogen and methane-oxygen-nitrogen mixtures,** *NACA TN* 3106, 30 pp., Feb. 1954.

A nonaqueous soap-bubble method was used to measure the burning velocities of some ethylene-oxygen-nitrogen and methane-oxygen-nitrogen mixtures. Burning velocity calculations were based on high-speed schlieren motion pictures of the flame growth and a theoretical expansion ratio. An upper limit in the spatial velocity in the range 2500 to 3500 cm/sec due to the appearance of rough flames was found for the bubble method. Soap-bubble burning velocities were compared with other methods. The agreement was good until the flames became rough.

From authors' summary by M. Gerstein, USA

2641. **Havemann, H. A., A theory of vortex combustion-chamber design: part 2,** *J. Inst. Fuel* **27**, no. 156, 25–34, Jan. 1954.

This is the second and final part of two articles [see AMR **7**, Rev. 1980 for part I] dealing with the design of vortex combustion chambers. The author's aim is to establish a range of design possibilities between limiting conditions rather than to give a particular solution. The design of the vortex entry and the combustion chamber are discussed and an example is worked out, using a graphical procedure. The relation is given between droplet size distribution and the radial dimensions of the chamber as well as the axial length of the chamber. A brief discussion of combustion, heat transfer, and ignition is also presented.

Since this paper is essentially theoretical in nature, it would be interesting to compare existing designs with those proposed by the author. Reviewer must repeat his criticism concerning the omission of the appendixes which contain the derivations of many of the formulas presented. R. S. Wick, USA

2642. Giffen, E., and Muraszew, A., The atomisation of liquid fuels, New York, John Wiley & Sons, Inc., 1953, x + 246 pp. $6.

Whenever liquid fuel is used as a source of heat (as in a furnace) or as a source of mechanical energy (as in internal-combustion engines, gas turbines, and jet engines), the fuel must first be atomized, i.e., broken up into small droplets, before combustion can take place. On the characteristics of atomization, i.e., on the degree of fineness and evenness of the spray, and on its distribution in space and time, depends to a large degree the efficiency of combustion, hence the economy of fuel utilization.

A great deal of research work has been expended and much still remains to be done in order to clarify the physical phenomenon of atomization, to assess the influence of the numerous variables of the fuel and the surrounding gas or air on the properties of the spray, to measure the significant properties, and thereby to give the practical problems of spray production a sound theoretical foundation. This is a difficult task because spray science comprises a number of disciplines, such as mathematics, physics, hydro- and aerodynamics, and mechanical engineering.

The book under review deals with the problems and methods of theoretical and experimental investigation of sprays. The authors, themselves meritorious contributors to this branch of science, have produced an authoritative and comprehensive treatise. There are ten chapters—about 70 sections and subsections—arranged in a logical sequence. Listing these will indicate the scope of the book:

Mechanism of disintegration of liquid jets; motion of small liquid drops in air; spray formation and penetration, energy of atomization and a survey of spray formation theories. Spray characteristics such as cone angle, dispersion, size, and uniformity of droplets. Effect of atomizer design on flow in atomizer, spray penetration, and cone angle. Theory of the swirl atomizer, air core, and cone angle. Dimensional analysis applied to the correlation of atomization data. Effect of physical properties of the liquid on spray dispersion, cone angle, velocity, and penetration. Effect of the properties of the gaseous medium on the spray properties. Effect of the injection pressure on spray penetration, cone angle, and droplet size. Formation and development of intermittent and continuous sprays; variation of pressure and velocity; progressive development of atomization. Experimental methods for the assessment of fuel-spray characteristics, of velocity, penetration, cone angle, structure, dispersion, droplet size; use of substitute liquids for droplet measurement.

A list of about 100 references is included. This is a well-balanced treatise, written in a lucid style, an excellent introduction and sound foundation for those concerned with atomized fuels. K. J. De Juhasz, USA

2643. Newton, F. C., Afterburners, are they worth while? *Aero. Engng. Rev.* **12**, 10, 42–47, Oct. 1953.

The question arises: Which is the better to use—turbojet with or without afterburning? A general analysis is made of the problem for fighter aircraft, based on current data available on engine design and performance and some basic aircraft design parameters. The results of the analysis indicate that, for a typical fighter with a design maximum level flight Mach number of 1.5 at 35,000 ft and a given military load, the power-plant configuration resulting in the lesser gross weight and hence cost is the basic engine without afterburning. From author's summary

2644. Davies, S. J., Combustion in compression-ignition oil engines, *Chartered mech. Engr.* **1**, 1, 24–36, Jan. 1954.

Article reviews experimental works on the title subject since 1931. In particular, author recalls the statement of Le Mesurier

and Stansfield about ignition lag and form of the curve of pressure rise; Hetzel's tests on fractional fuels; Davies' researches on evaporation and combustion of a single droplet of fuel; Ricardo's investigations upon performances of A.E.C. engine with and without supercharging; test results of Derry and others on effect of volatility and cetane number upon exhaust smoke density.

C. Codegone, Italy

2645. Cole, B. N., The physical nature of "knock." Calculations for pressure and temperature, *Engineering* **177,** 4591, 111–115, Jan. 1954.

2646. Hodson, P., The influence of fine particles on the corrosion of economizer and air preheater surfaces by flue gases, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-232, 21 pp.

The physical properties of a cloud of small particles ($< 10\mu$), or smoke, are discussed in considerable detail and it is suggested that these particles when present in boiler flue gases may, by virtue of their large surface area and adsorption properties, cause an increase in chemical and physical activity. In particular, they may accelerate the corrosion of metal surfaces by sulphuric acid condensing from the flue gas. They may also act as condensation nuclei. Some experimental, though only qualitative, evidence is put forward to support this from laboratory investigations.

These conclusions are to some extent at variance with other field and laboratory investigations which have shown that, while a small dust or smoke concentration may accelerate condensation (probably due to the factors discussed in this paper), higher concentrations, of the order of those mostly met in practice, tend to reduce corrosion—mainly by preventing the acid reaching the tube surfaces. [Kear, R. W., *J. appl. Chem.* **1,** p. 393, 1951; Littlejohn, R. F., ibid., **2,** p. 289, 1952; Corbett, P. F., and Flint, D., *J. Inst. Fuel* **25,** p. 410, 1953; Thurlow, G., ibid., **25,** p. 252, 1952.]

G. G. Thurlow, England

THE FOLLOWING REVIEWS (REVS. 2647–2682) WERE PUBLISHED IN Fourth Symposium (International) on Combustion, 1953; Baltimore, Md., Williams and Wilkins. $7.

2647. Altman, D., and Grant, A. F., Jr., Thermal theory of solid-propellant ignition by hot wires, 158–161.

Time required for ignition depends not only on power input and "ignition temperature" but on thermal conduction through system. Ignition occurs when self-heating exceeds rate of heat loss. The objective was to show that with well-defined boundary conditions, a mathematical solution of the heat-conduction equation incorporating the idea of ignition temperature leads to a satisfactory prediction of the data. Data considered are ignition energies obtained with a nichrome wire clamped between two pieces of propellant. Current and voltage were recorded on an oscillograph and the circuit was automatically broken when flame appeared. This gave dissipation and time; thence the total energy. The theoretical curve of ignition energy vs. ignition time generally agreed within the limits of error with the experimental results, but predicted rather low values of energy at long times (14–19 sec).

The theory is simplified by using one-dimensional equations, which, as authors state, is permissible if wire is thick enough. Authors' estimate of necessary size is, however, incorrect. They state, correctly, that the radius must be large compared with the thickness of the reacting layer, which is supposed to about 10^{-3} cm. But it must also be large compared with $(\kappa t)^{1/2}$, the distance an appreciable amount of heat flows in a medium of diffusivity κ in time t. For the propellant used, this is 0.12 cm after 10 sec, or more than twice the radius of the wire used. Evidently one should attribute discrepancies at long times to a failure of the theory as well as to the causes suggested. Furthermore, one would expect poorer agreement generally; and it seems probable that the theoretical curve is not very sensitive to the assumptions made. The relative success of Wimpress' equation, which is obviously deficient, also suggests this.

Reviewer appreciates the importance of ignition temperature to engineers, but endorses authors' emphasis on chemical considerations, which show that this quantity is only an apparent constant.

R. A. W. Hill, Scotland

2648. Simon, D. M., Belles, F. E., and Spakowski, A. D., Investigation and interpretation of the flammability region for some lean hydrocarbon-air mixtures, 126–138.

In this very interesting paper an interpretation is given to the empirical relations between important flame properties such as burning velocities, concentration limits of flammability, and quenching distances. The interpretation is based on the diffusion theory of C. Tanford and R. N. Pease and on the assumption that active radicals are destroyed on the surface in the quenching process.

The proposed equations provide a method of estimating low-pressure flammability limits and quenching distances for lean hydrocarbon air flames.

Although reviewer does not agree with some assumptions made by the authors, he would like to underline that interpretations of this kind, essentially derived from the kinetical and diffusional point of view, contribute to a better understanding of the flame phenomenon. The advantage lies in the fact that the individual behavior of molecules and radicals is considered instead of deriving tedious mathematical computations on the thermodynamic properties of the flammable mixture taken, as a whole, at different points of the flame front.

A. Van Tiggelen, Belgium

2649. Morgan, G. H., and Kane, W. R., Some effects of inert diluents on flame speeds and temperatures, 313–320.

This is a survey paper on the effect of inert diluents on the flame speeds and temperatures of stoichiometric mixtures of various gaseous fuels and oxygen. As part of a long-term program, it is only intended to furnish approximate rather than definite experimental values. The fuels used are methane, propane, acetylene, and hydrogen; the diluents are nitrogen, argon, and helium. Flame speeds are determined by the area method, taking as the flame front the schlieren image of the inner cone; temperatures are measured by sodium-line reversal.

The addition of small amounts of helium to hydrocarbon mixtures appears to give slightly higher flame speeds than those observed with no diluent, but neither argon nor nitrogen produce this effect. At very high concentrations of diluent, the spectral-line-reversal temperatures somewhat exceed the calculated adiabatic temperatures.

A discussion of these and other results is included.

R. Delbourgo, France

2650. Mellish, C. E., and Linnett, J. W., The influence of inert gases on some flame phenomena, 407–420.

The effect of inert gas substitutions (helium, argon, nitrogen, carbon dioxide) is studied experimentally (1) on burning velocities of $C_2H_4 + O_2$ + inert gas, (2) on the upper limits of inflammability of H_2 + air + inert gas, and of $H_2 + N_2O$ + inert gas. The burning velocities are determined by the soap-bubble method; the limits of inflammability in a vertical tube 150 cm long and 5 cm in diam, closed at the top.

The results are compared to those of other authors. Moreover, spark-ignition phenomena (minimum ignition pressure and minimum ignition energy) and quenching distances are taken into consideration in discussing the effects of changing inert gases. It is concluded that radical diffusion seems to be more important than thermal conduction in governing the flame speeds, while the reverse may be valid for quenching distances. As for the limits of inflammability and the spark-ignition phenomena, the thermal conduction may be as important as radical diffusion.

H. Behrens, Germany

2651. **Egerton, A., and Sen, D., Flame propagation: the influence of pressure on the burning velocities of flat flames,** 321–328.

Authors review previous work on pressure influence on burning velocities of flames. Using the flat flame developed by Egerton and Thabet, they record new experimental evaluation of burning velocities for fuel/air mixtures of propane, ethylene, acetylene, methane, and carbon disulphide, in the range of pressures 150–550 mm. Also data on CO/air flames are given. From plots of log (burning velocity) against log pressure, authors infer that for methane, acetylene, and carbon disulphide the burning velocity $V_B = p^{-1/2}$, whereas for propane and ethylene $V_B = p^{-1/3}$. For ethylene, some change in combustion mechanism is indicated around 400-mm pressure. While the thermal theory of flame propagation can account for the findings with methane and carbon disulphide, the incidence of other factors such as the diffusion of hydrogen atoms in the flame is not ruled out, particularly for ethylene and propane. A. R. Ubbelohde, Ireland

2652. **Putnam, A. A., and Smith, L. R., On the extinction limit of laminar flames,** 708–714.

For a given combustible mixture and a Bunsen burner of given size, there is a pressure below which a flame cannot be maintained at any flow rate; i.e., the flash-back and blowoff curves converge here. This extinction limit is discussed in terms of dimensionless groups obtained from a thermal model based upon the concept that a minimum thickness δ of the flame must be above an ignition temperature T_i. No attempt is made to evaluate δ or T_i from extinction-limit data. However, such data, obtained with Bunsen burners, as well as stability data for an axial rod flame holder, with and without applied dc fields, are shown to correlate in dimensionless plots. The significance of this work is not entirely clear to reviewer. R. Friedman, USA

2653. **Clingman, W. H., Brokaw, R. S., and Pease, R. N., Burning velocities of methane with nitrogen-oxygen, argon-oxygen, and helium-oxygen mixtures,** 310–313.

Authors have determined the burning velocities of methane-nitrogen-oxygen, methane-argon-oxygen, and methane-helium-oxygen mixtures, at one atmosphere pressure and at an initial temperature of 25 C for the unburned gas. The experimental results are correlated with values calculated from a consideration of the diffusion of hydrogen atoms, hydroxyl radicals, and oxygen atoms from the flame front into the unburned gas.

The burning velocities were determined by means of the Bunsen-burner method using a shadowgraph technique and total areas at different distances from the burner according to the method of Andersen and Fein.

The experimental results are correlated with relative values calculated from the diffusion theory of Tanford and Pease, also with relative values calculated from the same modified theory in which the temperature dependence of the diffusion coefficients is taken into account by assuming a linear temperature gradient for the reaction zone.

The Pease and Tanford theory was used to calculate the absolute burning velocity of a methane-argon-air mixture containing 9.46% methane. The calculated value was 352 cm/sec, compared with an experimental value of 93.4 cm/sec, while a similar calculation using the modified form of the Pease and Tanford theory leads to a value of 165 cm/sec for the absolute burning velocity.

R. Delbourgo, France

2654. **Grumer, J., Harris, M. E., and Schultz, H., Flame stabilization on burners with short ports or noncircular ports,** 695–701.

In previous work done with cylindrical burners having a circular flame port and Poiseuille flow (and, by other investigations, turbulent flow) it has been established that, for each fuel, the flash-back (or blowoff) characteristics can be specified by a curve in which the critical boundary velocity gradient at which flash-back (or blowoff) occurs is plotted against the fuel-air mixture being burned. Flame stability characteristics of flames on sharp-edged, short cylindrical ports "of the type found on the usual gas appliance" are shown to obey the same critical boundary velocity gradient criteria.

Experiments were performed using burners having long channels of uniform square, rectangular, or triangular cross section. Gas was in laminar flow. It was shown that theoretically computed velocity gradients are distorted by the flame. By taking this correction into account, the flame stability dependence on critical boundary velocity gradient is shown to apply, as in the case of burners having circular ports. R. Cornog, USA

2655. **Phillips, V. D., Brotherton, T. D., and Anderson, R. C., Physical characteristics and stability of some low-temperatured flames: the hydrogen-bromine system,** 701–707.

Mixtures of hydrogen and bromine were burned in an atmosphere of carbon dioxide by means of a special Bunsen-type burner. Temperatures in the burning gas, boundary velocity gradients for flash-back and blowoff, and limiting tube diameters for quenching were measured. Experimental results are presented and discussed. R. Cornog, USA

2656. **Bowditch, F. W., Some effects of turbulence on combustion,** 674–681.

Majority of flames found in practice are supported by turbulent rather than laminar combustible mixtures. Accurate assessment of the role of turbulence in combustion would assist in many practical applications. Author examined the effect of turbulence on a flame of commercial propane in air stabilized by small auxiliary flames on the extension from a rectangular nozzle. Turbulent intensity was varied between 1.55 and 7% by screens of different mesh placed at selected distances upstream between extension and nozzle. Apparent burning velocity, determined by measurement of flame angle, was found to vary less with turbulent intensity than did the actual burning velocity obtained from measurements, from shadowgraph photographs, of flame convolutions. Empirical correlation $S_T = S_L \exp 1.15\, v'/S_L$ was obtained between turbulent velocity v', apparent turbulent burning velocity S_T, and laminar burning velocity S_L. No correlation was found between turbulent scale (varied from 0.038 to 0.11 in.) and S_T, in agreement with previous theories and experimental work. Reviewer would point out that the v' values used refer to turbulent intensity in the cross section of main stream where ignition is first effected by pilot flames and not at representative points along the wedge-shaped flame front. Maximum difference between turbulent velocity at ignition cross section and flame front at wedge tip was about 10 in./sec, ignoring possible effects of the presence of the flame. Use of flame piloting adds further limitations to use of correlation by giving rise to an apparent laminar burning velocity of 59.8 in./sec. D. B. Leason, England

2657. Starkman, E. S., Haxby, L. P., and Cattaneo, A. G., A study of free flames in turbulent streams, 670–673.

Authors examine ignitibility of some fuel and air mixtures under flowing conditions. An experimental method has been devised wherein a transparent duct of constant area is used and standard state volume and temperature conditions are maintained during combustion. They show an unexplained initial increase in air-fuel ratio lean limit before the expected decrease as velocity is increased. Rich and lean limits approach stoichiometric as velocity is increased, as is expected. Decreasing pressures affect lean limit only. Reviewer believes lower velocity lean-limit values need further study to discount wall effects.

F. W. Bowditch, USA

2658. Schultz-Grunow, F., Similarity laws of deflagration, 439–443.

In combustion problems, formal laws governing burning speed are valuable. The simple expression obtained earlier by dimensional analysis is insufficient. Author points out that dimensionless burning speed ω must be a function of four (not one) dimensionless parameters, $\omega = f(\varphi_1, \varphi_2, \varphi_3, \varphi_4)$, φ_4 being the order of combustion reaction. For experiments taken from literature, values of the parameters have been calculated for (N_2-O_2-H_2). ω plotted versus φ_1 ($=qc/Tc_p\gamma$, q heat of reaction, c concentration of one component, T temperature, c_p specific heat, γ density) gives an almost smooth curve for constant values of the other parameters.

Reviewer believes that several implicit assumptions have been introduced; among others, reaction (1) involves two relevant reactants only, and (2) proceeds by simple mechanism, determined by reaction order. Without (1), more dimensionless parameters would enter. Assumption (2) might be essential for whole argument.

W. Jost, Germany

2659. Kihara, T., and Kikita, T., Equation of state for hot dense gases and molecular theory of detonation, 458–464.

The intermolecular potential $U(r) = \lambda r^{-n} (\lambda > 0, n > 3)$ is used to introduce a theoretical equation of state for high-temperature gases, and its application to detonation phenomena is considered. Under the assumption of a fixed decomposition equation, the variation of detonation velocity with loading density is explained satisfactorily for PETN, TNT, and tetryl in the case of $n = 9$.

From authors' summary by J. A. Fay, USA

2660. Ubbelohde, A. R., The possibility of weak detonation waves, 464–467.

Weak detonations considered are those with small heat release but not necessarily without a shock wave preceding the heat release. Author states that critical size of charge is required to permit weak detonation, the size increasing with decreasing reaction rate. The possibility of some geological weak detonations is considered.

J. A. Fay, USA

2661. Oppenheim, A. K., Gasdynamic analysis of the development of gaseous detonation and its hydraulic analogy, 471–480.

The development of a gaseous detonation wave from the coalescence of a combustion front and a shock wave is considered. The combustion front is treated as a discontinuity propagating at sound speed with respect to the burned gases, and with change of state and velocity in accordance with steady-flow laws. The regions ahead, between, and behind the double discontinuity are considered to be of uniform state and velocity so that unsteady plane wave effects are not considered. Under these conditions it is shown that the maximum pressure occurring during the development is greater than the Chapman-Jouguet pressure. A hydraulic analogy to this system is described.

J. A. Fay, USA

2662. Paterson, S., Contact transmission of detonation, 468–471.

Author considers the strength and character of the transmitted and reflected waves produced by the impingement of a detonation wave on an interface between the reactive medium and (a) a nonreactive one and (b) another reactive medium. In case (a), a shock wave is transmitted and a shock or expansion wave reflected. In case (b), an accelerating (nonsteady) detonation or an "overdriven" detonation may be transmitted. Reviewer believes that first alternative in (b) is physically unrealistic and that a transmitted wave involving a normal detonation followed by a simple expansion wave would suffice.

J. A. Fay, USA

2663. Bowden, F. P., The development of combustion and explosion in liquids and solids, 161–172.

Investigation of physical conditions required to initiate combustion and detonation in liquid and solid explosives is described. Propagation of low-velocity detonation in secondary explosives, combustion and detonation in azides, and initiation and combustion in gun powder are each handled separately. Initiation by momentary hot spots formed by adiabatic compression and by friction is reported. With hot-spot formation avoided, very extreme conditions produced initiation by viscous heating. This paper extends the outstanding contributions in this field published earlier by F. P. Bowden and A. D. Yoffe in "The initiation and growth of explosions in liquids and solids," Cambridge Univ. Press, 1952.

M. Sultanoff, USA

2664. Blackshear, P. L., Jr., Driving standing waves by heat addition, 553–566.

See AMR 6, Rev. 1721.

2665. Sultanoff, M., Detonation and shock in a hollow explosive cylinder, 494–497.

The development of a shock wave inside a hollow detonating pentolite cylinder was photographed by streak and high-speed cameras. It was found that the shock wave so formed propagated at a higher velocity than the detonation in the pentolite.

J. A. Fay, USA

2666. Manson, N., and Ferrie, F., Contribution to the study of spherical detonation waves, 486–494.

Spherical-detonation wave velocities were measured in mixtures of oxygen with acetylene, propane, ethylene plus methane, or St. Marcet gas. The velocities did not differ from those measured in tubes, within the experimental error All such mixtures required a detonator to initiate a spherical detonation except oxygen-acetylene, which required only a commercial igniter with electric primer. No spherical-detonation waves were obtainable in any of the fuels mixed with air. The composition limits of detonation were not as broad as those measured in tubes. Authors conclude that a strong spherical shock wave is necessary to induce spherical detonation.

J. A. Fay, USA

2667. Deffet, L., De Coster, M., and Vande Wouwer, P. J., Study of the mechanism of transmission of detonation, 481–485.

Mixed charges of 18-mm core and 36-mm sheath diam (sheath explosive having much lower detonation velocity than the core) were detonated to determine how the detonation is transmitted from the core to the sheath. It was found that the charge detonates with the proper velocity of the core, but that the detonation front in the sheath (at its outer edge) is 10 mm behind that in the core. When the mixed charge was primed directly, the sheath initially failed to detonate. Authors believe, however, that sheath participates in initial process by deflagration or weak detonation.

J. A. Fay, USA

2668. **Brinkley, S. R., Jr., and Richardson, J. M., On the structure of plane detonation waves with finite reaction velocity,** 450–457.

Authors follow von Neuman's analysis of the structure of a detonation wave in considering a "subideal Chapman-Jouquet detonation wave," defined as one in which the reaction "freezes" before completion. (This, however, implies a reaction rate discontinuous with temperature.) The properties of the subideal wave are found to be the same as those for an ideal wave with the same heat release. The velocity of sound in a reacting medium is found in terms of the partial derivative of the pressure with respect to the density. J. A. Fay, USA

2669. **Smith, R. P., and Sprenger, D. F., Combustion instability in solid-propellant rockets,** 893–906.

This paper describes experimental work on solid-propellant rocket motors in which high-frequency combustion instability is encountered. This type of instability is characterized by the presence of high-amplitude wave motion within the combustion chamber. Authors, by employing high-response pressure gages strategically placed both along the circumference and length of the motor, obtained evidence indicating that the wave motion is of a type similar to that predicted by acoustic theory for cylindrical coordinates. Authors concluded that the source of energy for these high-frequency, high-amplitude waves must come directly from the combustion processes rather than from the kinetic energy of the axial gas flow. Wave phenomena observed appear to be closely related to the phenomena of spinning detonations [see Fay, J. A., AMR **6**, Rev. 1100]. Reviewer feels that authors have done an excellent job in applying a combined experimental and theoretical approach to a very complicated problem.

R. W. Wick, USA

2670. **Crocco, L., and Cheng, S.-I., High frequency combustion instability in rockets with distributed combustion,** 865–880.

This theoretical analysis of the growth of axial high-amplitude pressure waves which travel back and forth between injector face and nozzle of a rocket motor is an extension of the senior author's paper [AMR **5**, Rev. 2713] on the theory of high-frequency combustion instability in rockets with the combustion concentrated at the injector face. The present paper deals with a more realistic model of the liquid-propellant rocket combustion chamber than the earlier paper. The combustion process is assumed to be distributed linearly along the length of the combustion chamber, and a more realistic boundary condition was used for the nozzle end of the chamber [see paper by senior author, AMR **7**, Rev. 608]. This constitutes the principal difference between the present paper and the first paper [op. cit.]. Authors' results indicate that spreading combustion out along the length of the combustion chamber improves combustion stability over the case where combustion is concentrated at the injector face.

R. W. Wick, USA

2671. **Maxwell, W. R., Pyrotechnic whistles,** 906–914.

2672. **Garner, F. H., Long, R., and Thorley, B., A comparison of schlieren, shadow and luminous methods of determining burning velocities,** 386–391.

Methods of determining burning velocities from measurements on Bunsen burner flames are discussed. Differences arising from application of the Guoy-point method to different regions of the luminous, shadow, and schlieren cones are investigated for benzene/air mixtures in a 1-cm burner.

Curves of apparent burning velocity vs. r/R (r flame radius at point of measurement, R burner radius) for the three cone surfaces give schlieren and luminous curves of the same shape—the former lying above the latter. The shadow curve has a radically different shape. It intersects the luminous curve at an r/R value slightly less than 0.4. This value corresponds to the point of inflection of the schlieren curve, and the point at which the tangents to the shadow and luminous surfaces are parallel. At this point, true burning velocities can be calculated by the Guoy relationship with an estimated accuracy of about 5%.

Results show none of the surfaces taken singly is ideally suitable and the Bunsen cone is geometrically unsuitable for burning-velocity determination. E. Baicy, USA

2673. **Egerton, A. C., Saunders, O. A., Lefebvre, A. H., and Moore, N. P. W., Some observations by schlieren technique of the propagation of flames in a closed vessel,** 396–402.

A study has been made of the characteristics of flame propagation through hydrocarbon/air mixtures in a container of constant volume, the primary object being to reproduce under controlled laboratory conditions the actual combustion processes occurring in the cylinder of an internal-combustion engine. Preliminary investigation has provided many interesting records, including photographs which show in fine detail the development of pre-reactions in the region ahead of the spark-ignited flame and which eventually lead to autoignition and knock. These records also explain many a knocking combustion in an engine cylinder. Photographs have been obtained to show that the combustion of methane is not always by a single-stage process as has been hitherto supposed and as the recent gas-sampling experiments of Downs and Wheeler have also indicated.

The associated phenomena of "cool flame" and two-stage ignition have also been studied in their relation to autoignition and knock. From authors' summary by P. Laffitte, France

2674. **Egerton, A. C., Everett, A. J., and Minkoff, G. J., High-speed (3000 frames/sec.) photography of low pressure, spark-ignited explosions of methane and of hydrogen in oxygen,** 392–395.

Authors have studied low-pressure flame velocities both at room temperature and at −186 C. A high-speed (3000 frames/sec) photographic technique was used. This study aimed to examine sudden changes in the mode of flame propagation, these changes furnishing a possible explanation of the shape of the curves plotted for log (peroxide/fuel burned) against log (pressure) for low-pressure explosions of hydrogen and methane in vessels cooled at low temperatures. These curves show a sharp bent at some critical pressure. Photographs show a glow which fills the tube and then decays in a length of time often much greater than the duration of the explosion itself. This glow is also observed in hydrogen explosions and it is possible that the glow is caused by the recombination of atoms on the walls or in the body of the gas.

P. Laffitte, France

2675. **Schmidt, E. H. W., Steinicke, H., and Neubert, U., Flame and schlieren photographs of combustion waves in tubes,** 658–666.

See AMR **4**, Rev. 4605.

2676. **Leah, A. S., and Carpenter, N., The estimation of atomic oxygen in open flames and the measurement of temperature,** 274–285.

The temperatures just above the inner cone of CO-O_2, CO-air, propane-air, ethylene-air, and benzene-air Bunsen flames are measured by three different methods: (a) Sodium-line-reversal, (b) resistance thermometer, and (c) electrically heated resistance wire (method of Schmidt, Kohn, etc.). The results show agreement between line-reversal and heated uncoated-wire temperatures, as earlier investigators have found. However, both heated and unheated quartz-coated wires give temperatures several

hundred degrees lower, after appropriate radiation corrections are made. The authors conclude that (a) the flame gases are not in equilibrium for a considerable height above the inner cone tip, (b) the line-reversal method gives high results since Na may be excited chemically by reactions such as $CO + O + Na \rightarrow CO_2 + Na^*$, (c) uncoated wires give high results (sometimes fortuitously agreeing with line-reversal values) because of catalytic effects. For the case of CO-O_2 mixtures, the results are consistent with the view that relatively high concentrations of oxygen atoms remain in the flame gases above the inner zone for as long as 10 msec. This investigation appears to be a careful and valuable piece of work. R. Friedman, USA

2677. Gilbert, M., and Lobdell, J. H., Resistance-thermometer measurements in a low-pressure flame, 285–294.

Valid temperature measurements in high-temperature gas streams have long been an important problem in both scientific and engineering applications because of heat-transfer corrections. An electrically heated wire is employed in a low-pressure flame and the wire temperature is observed as a function of the heating current. A plot of the electrical plus radiative energy of the wire against wire temperature is a straight line extrapolating to the gas temperature as intercept. Technique differs from null method employed by Schmidt [*Ann. Phys., Leipzig* **29**, 971–1028, 1909], since wire need not be at flame temperature. This difference makes possible the measurement of flame temperatures exceeding the melting point of the wire by as much as 500 C. The novel method of plotting the data permits a direct experimental evaluation of the thermal conductivity of the gas. Author also discusses several methods of correcting for surface catalysis, when present. D. Altman, USA

2678. Friedman, R., Measurement of the temperature profile in a laminar flame, 259–263.

Actual temperature profile in a flame is important in understanding flame propagation and verification of kinetic combustion mechanisms. The temperature profile in a plot propane-air flame is measured with a fine platinum thermocouple 0.0005 cm in diam coated with N. B. S. ceramic coating A-418 to eliminate surface catalytic effects. A solution to the heat-conduction equation is given and the temperature at which the experimental data break away is interpreted to be the point of exothermic reaction. Heat release is found to start at about 1150 K in a zone 0.05 cm thick, and the reaction time is about 1.7×10^{-3} sec.
D. Altman, USA

2679. Hall, A. R., and Diederichsen, J., An experimental study of the burning of single drops of fuel in air at pressures up to twenty atmospheres, 837–846.

Paper gives experimental investigation of burning of kerosene, furfuryl alcohol, tetralin, decane, and amyl acetate in air (a) by observing droplets injected into furnace at atmospheric pressure, (b) by photographing suspended burning droplets at elevated pressures. Experiments (a) showed, qualitatively, ignition and steady burning, followed by "explosion" of droplet; (b) showed, quantitatively, burning rate proportional to droplet diameter times fourth root of absolute pressure. Some experiments on vaporization of water droplets with radiant heating were carried out in same apparatus. D. B. Spalding, England

2680. Spalding, D. B., The combustion of liquid fuels, 847–864.

Burning rates of single particles of liquid and solid fuel are considered theoretically and experimentally. This paper presents a convenient method for estimating burning rates and extinction limits. Results are given in terms of a transfer number B. For solid fuels, diffusion alone controls burning rate and no heat equation is needed. For liquid fuels (or, reviewer adds, solids which vaporize), vaporization requires the use of a heat equation. For carbon, burning rate is independent of whether or not there is a gas phase reaction, but depends on the nature of surface reaction. For metals with nonvolatile oxides, B approaches -1. For liquids, B decreases as volatility decreases. Numerical values are listed for a variety of fuels. Experiments using a porous sphere uniformly wet with liquid fuel verified the theory. M. Gerstein, USA

2681. Gregory, C. A., Jr., and Calcote, H. F., Combustion studies of droplet-vapor systems, 830–836.

Droplet-vapor reactions have been examined as part of a study of liquid rocket-propellant combustion. Single droplet behavior is investigated by causing a droplet of one reactant to fall through a known length of the gaseous phase of the other reactant with provision for observing the time of fall before ignition, using two photocells. A two-stage reaction tube is used and the droplets are formed at the tip of a hypodermic needle. Constructional details of all items are given, together with experimental procedure. Preliminary results relate to a number of different reactants in hydrazine vapor and, whereas the ignition delays recorded cannot be directly correlated with rocket performance, the approach appears capable of extension.
D. A. Scholefield, England

2682. Godsave, G. A. E., Studies of the combustion of drops in a fuel spray—the burning of single drops of fuel, 818–830.

Theoretical relation is derived for constant-pressure vaporization from a convex spherical surface, the heat source being a concentric sphere of larger diameter. Constant fluid properties are assumed. Theory is applied to experimental data on burning rates of hydrocarbon droplets suspended in still air, heat source being visible flame region, assumed to be at adiabatic flame temperature of stoichiometric fuel-air mixture. Theoretical and experimental rates are in good agreement despite considerable departure of flame from assumed spherical form caused by natural convection. Application of theory to other conditions is limited by necessity for information on distance of flame from liquid surface. Experiments show clearly the unimportance of molecular structure compared with enthalpy change on vaporization. D. B. Spalding, England

Acoustics

(See also Revs. 2619, 2669, 2670)

2683. Kemp, G. T., and Nolle, A. W., The attenuation of sound in small tubes, *J. acoust. Soc. Amer.* **24,** 6, 1083–1086, Nov. 1953.

Measurements were made of the attenuation of sound in dry air as a function of frequency (from 3.8 to 20 kilocycles) and of tube diameter. A standing wave system was used and the attenuation was measured by the increase in minima as a function of length. The attenuation measured could be represented by a formula of the form $\alpha = Af^{1/2} + Bf$. The Kirchhoff theoretical value, which indicates an increase of attenuation proportional to the square root of the frequency and inversely proportional to the tube radius, was compared with the measured value of $Af^{1/2}$ and was found to be in good agreement. No explanation is offered for the component of attenuation proportional to the frequency.
W. P. Mason, USA

2684. Kraichnan, R. H., The scattering of sound in a turbulent medium, *J. acoust. Soc. Amer.* **24,** 6, 1096–1104, Nov. 1953.

Author attacks the problem of the diffraction of sound by a

region of turbulence in a way very similar to that of a recent paper by M. J. Lighthill [AMR **7**, Rev. 864] which, however, was unknown to author at the time of his writing.

After a concise summary and a thorough discussion of the basic equations which govern the interaction of sound and turbulent flows with methods similar to those used by Lighthill [AMR 6, Rev. 654] and Moyal [AMR **6**, Rev. 224], author solves the problem of the scattering of an acoustic wave by a finite region of shear flow of low Mach number. Expressions for the scattered intensity are obtained as functions of angle and frequency. These formulas are finally evaluated and represented graphically for the scattering of a plane wave of sound by a region of isotropic turbulence. H. L. Oestreicher, USA

2685. **Angona, F. A., Apparatus and procedure for measuring the absorption of sound in gases by the tube method,** *J. acoust. Soc. Amer.* **24,** 6, 1111–1115, Nov. 1953.

Development of tube apparatus to measure molecular absorption of sound in gases is described. Advantages of apparatus are: Accurate control of pressure and, thus, of absorption peak; only small quantity of gas required; intense sound field permits measurement of highly absorbent gases. P. H. Parkin, England

2686. **Mintzer, D., Wave propagation in a randomly inhomogeneous medium. II,** *J. acoust. Soc. Amer.* **24,** 6, 1107–1110, Nov. 1953.

Paper is a continuation of a previous one with the same title [AMR **7**, 1027]. It develops a second approximation to the solution of the problem solved in first approximation—the propagation of sound impulses in a medium whose index of refraction has small random variations about the mean value 1. This second approximation is then used to determine the region of validity of the approximate solution derived in the first paper. It is found that the first approximation is valid provided that $k_0^2 a r \alpha^2$ is very much less than unity, where k_0 is the wave number of the incident sound, r the distance from source to observer, a the mean size of the inhomogeneities, and α is the rms value of the variations in the refractive index. Thus, for the case of 24kc sound and $a = 60$ cm, $\alpha^2 = 5 \times 10^{-9}$, the first approximation is valid for $k_0 r$ very much less than 3×10^6. This condition is certainly satisfied for the experiments of M. J. Sheehy [AMR **4**, Rev. 3066] discussed in the earlier paper. I. N. Sneddon, England

2687. **Heller, G. S., Reflection of acoustic waves from an inhomogeneous fluid medium. I,** *J. acoust. Soc. Amer.* **24,** 6, 1104–1106, Nov. 1953.

Paper gives an approximate method of calculating the reflection coefficient of plane waves for oblique incidence in the case of a homogeneous fluid medium separated by a plane interface from a nonhomogeneous medium. The method used is the Wentzel-Kramers-Brillouin asymptotic solution of the differential equation. A complete account of the theory on which this method is based is given by Jeffreys, *Proc. Lond. math. Soc.* **23,** 428, 1924. Author compares his approximate results with the exact results in the case in which the wave velocity in the second medium is exponential, for which he derives an exact solution in terms of Hankel functions. Good agreement is obtained—5% over-all—with better agreement for grazing and normal incidence. It is likely that the method will be reliable for fields of exponential type. J. M. Jackson, Scotland

2688. **Angona, F. A., The absorption of sound in gas mixtures,** *J. acoust. Soc. Amer.* **25,** 6, 1116–1122, Nov. 1953.

The absorption of sound has been measured in CO_2, CS_2, C_2H_6O, and in mixtures of the latter two gases with CO_2 for frequences ranging from 2 to 10 kc and for pressures ranging from 3 to 300 mm of Hg. The tube method was employed. The absorption was determined by observing the decrease in sound pressure as the path length between the speaker and the microphone was increased. A fixed condensor microphone and a movable ribbon-type speaker were used.

The measured absorption coefficient was corrected for the effect of the tube and also for the absorption due to viscosity and heat conduction of the gas. The corrected absorption coefficient was then plotted as the attenuation coefficient per wave length against the logarithm of the ratio of frequency over pressure. These curves were then compared to those determined from Bourgin's theory for mixtures of absorbing gases. The agreement between the observed attenuation and that predicted by the theory was within 5%.

From author's summary by R. D. Spence, USA

2689. **Bhadra, T. C., On the generation of high intensity ultrasonic energy and measurement of the output power density of a quartz crystal,** *Indian J. Phys.* **27,** 10, 496–503, 1 fig., Oct. 1953.

The upper limit of ultrasonic energy, generated by a quartz crystal, is generally believed to be about 40 W/cm^2, while calculations by Morse, Cady, and others show that the mechanical breakdown of the crystal would occur within the order of 10^4 W/cm^2. Author succeeded in measuring an output of 42.2 W/cm^2 with an X-cut crystal of 6.25 cm^2 area and a thickness of 0.287 cm (1000 kcps), and the crystal being air-backed or lead-backed. The power output is measured calorimetrically. It is believed that the distortion of the crystal is caused by the breakdown of the dielectric fluid (like transformer oil) and the inhomogeneous heating of the crystal by the electric arcs near the crystal. Some incidental observations in connection with power measurements are included. O. Ruediger, Germany

2690. **Schmid, G., and Knapp, H., Ultrasonic transmission through porous bodies in liquids** (in German), *Z. angew. Phys.* **5,** 12, 463–472, Dec. 1953.

In this experimental study, ceramic disks with 0.3 micron pores were immersed in a 0.001 normal (KCl) solution excited by 350 kcps ultrasound. Intensities were below cavitation, and disk thickness varied from about $^1/_4$ to 2 wave lengths. A series of electrodes spaced throughout the disk picked up the electrokinetic potential from the fluid flow relative to the disk. For some thicknesses, the potential between surface and adjacent electrode was much greater than the over-all potential. Minima in the potential-thickness relation did not occur at the half-wave-length positions predicted. To clarify these results there was constructed an analog model with two series of pendulums, coupled by a common fluid resistance as in the disk. Model frequencies were of the order of 2 cps. The phase of the absolute fluid velocity was found to change more rapidly than that of the disk matrix. No quantitative theoretical explanation is offered.

V. Salmon, USA

2691. **Smith, A. H., and Lawson, A. W., The velocity of sound in water as a function of temperature and pressure,** *J. chem. Phys.* **22,** 3, 351–359, Mar. 1954.

Authors measure the velocity of sound in degassed water under hydrostatic pressures varying up to 9600 kg/cm^2 and at various temperatures between −12 C and 129 C. Method of measurement involves ultrasonic echo techniques. Isobaric and isothermal curves are obtained for variation of velocity of sound. A new feature is the result that the temperature at which velocity of sound is a maximum is found to increase as pressure increases;

result is compared with Holton's work, where converse was observed. Critical analysis of results is followed by discussion of recent theories of structure of water.

Reviewer believes paper contains new results and stimulating approach to the problem. D. H. Trevena, Wales

2692. Pryor, A. W., and Roscoe, R., The velocity and absorption of sound in aqueous sugar solutions, *Proc. phys. Soc. Lond.* (*B*) **67,** 409, part 1, 70–81, Jan. 1954.

The absorption and velocity of ultrasonic waves have been measured in aqueous sugar solutions of concentrations ranging from 20 to 60% by weight at frequencies between 5 and 25 mc/s over a temperature range of 20 to 60 C. The velocity results indicate that the sugar molecules have "solvation envelopes" (attached layers of water molecules) which decrease in thickness as the temperature increases. The ratio of the actual absorption to the classical absorption is close to the value in pure water (3.1) at all concentrations, while elementary considerations suggest that it should decrease toward unity as the concentration increases. Further theoretical considerations reveal an additional source of energy dissipation at high concentrations arising from the high local viscous stresses which result from squeezing out water molecules when the solution is compressed. For pure associated liquids which contain two different states of molecular arrangement, one crystalline and one disordered, one should expect a ratio of about 2.25, while the observed values for alcohols and water are 1.64 to 3.10. This suggests that structural relaxation, if it occurs at all, is responsible for only a small portion of the excess absorption. M. S. Weinstein, USA

2693. Walters, A. G., The noise from aircraft, *J. roy. aero. Soc.* **58,** 517, 65–71, Jan. 1954.

A general expression based on linear theory is obtained for the potential of sound or aerodynamic disturbance from a source moving with variable vector velocity. When the space-time curve for the source is known, the Doppler frequency corrections and intensities can be determined. If, in any part of its trajectory, the aircraft exceeds the velocity of sound, the number of sonic bangs and the times of occurrence can be calculated. A numerical example is given. The conclusions are: (a) If at any point of its trajectory, the component of the aircraft velocity in the direction of the observer is equal to the velocity of sound, a sonic bang is propagated to the observer with the velocity of sound. (b) A bang determined by conclusion (a) comprises two components and, in certain circumstances, the components in some of the bangs may be acoustically separable, thus giving rise to double bangs. From author's summary by N. Tetervin, USA

2694. Weller, E. F., Acoustic apparatus for determination of mixture ratio by analysis of engine exhaust gas, *Anal. Chem.* **26,** 3, 488–491, Mar. 1954.

A mixture ratio analyzer was developed to provide a fast and accurate means of indicating or recording the air-fuel ratio in internal-combustion engines. The analyzer converts the raw engine exhaust gas to a two-gas mixture plus water vapor by the use of an oxidation furnace. The water vapor is held to a constant low value and the resultant binary mixture is analyzed in an acoustic chamber. The acoustic gas, analyzer operates by measuring the velocity of sound in the gas using a simple feedback circuit in which the acoustic chamber is the frequency controlling element. A frequency discriminator converts the signal to a direct current voltage which is a function of the gas composition. The analyzer will indicate or record mixture ratios with an error of ±1%; the drift is 1% in 24 hours. The accuracy achieved with this unit is comparable to the accuracy obtained with more elaborate equipment, while the response time is considerably shorter. In this application, the analyzer is more accurate and does not have the inherent errors found in the Orsat, and therefore it is more accurate than devices depending on the Orsat for dynamic calibration. From author's summary

2695. Powell, A., On edge tones and associated phenomena, *Acustica* **3,** 4, 233–243, 1953.

Observations of edge-tone phenomena may explain how sound waves give rise to stream disturbances at the jet orifice. An exact theoretical solution is not yet possible. However, jumps of frequency and associated hysteresis effects can be discussed.

E. G. Fischer, USA

Ballistics, Detonics (Explosions)

(See also Rev. 2532)

2696. Lawden, D. F., Minimal rocket trajectories, *J. Amer. Rocket Soc.* **23,** 6, 360–367, 382; Nov.-Dec. 1953.

The problem of the navigation of a rocket vehicle between two fixed terminals in space, in such a manner as to minimize the fuel expenditure, is analyzed in a general fashion, account being taken of a gravitational field, variable in space and time. The motion is assumed to take place in vacuo. The transit time may or may not be regarded as specified. The solution trajectory is shown to comprise a number of null-thrust arcs, separated by junctions at which impulse thrusts are applied. The conditions to be satisfied at these junctions are calculated. The theory is applied to the special case of the optimal transfer of a rocket between two coplanar elliptical orbits about a center of attraction.

From author's summary by E. W. Price, USA

2697. Protte, B., The recoilless rifle (in French), *Mem. Artill. fr.* **27,** 1, 131–138, 1953.

In a short historical review, author points out that the first patent was granted to Davis in America. The French air forces used the same idea in a gun mounted and tested on a Voisin airplane during 1914–1918. In 1921, Charles A. Cooke proposed his "nonrecoil gun" and his solution is the one now used in modern recoilless weapons. The first weapon put into field service was German, in 1943. After some experiments with smaller weapons, the United States placed in production in January, 1944, the 57 mm M-18 and in August, 1944, the 75 mm M-20 which arrived in the field in March, 1945.

The theoretical part of the study is given in three sections:

I For his analysis of the burning phase, author uses the classical inertia equation of internal ballistics, $mvdv = Pdc$, and the equation of burning due to Charbonier, $dz/dt = AP\varphi(z)$. In the inertia equation a correction is introduced to account for the loss of heat due to exit of powder gas. In this manner, author arrives at the definitive equation of burning, $dz/dt = A_0(P + B)\varphi(z)$. Here B is a constant depending on temperature and on the linear velocity of propagation of burning of the powder.

II In the study of the exit phase, a modified energy equation is used, solved step by step in segments with s as argument.

III Material equilibrium is established in so far as possible during every instant during the whole process. Author arrives at an equation for material equilibrium based on the ratios of $k = c_p/c_v = 1.25$, as follows: $\lambda\Sigma/\sigma[X\{10[1 - (P_s/P)^{0.2}]\}^{1/2} + P_s/P \cdot \Sigma_s/\Sigma] = 1$. Here λ is a coefficient (value of approximately 0.9 which accounts for all minor approximations introduced in the analysis, P_s and Σ_s are the pressure and the muzzle area at the chamber end, P and Σ are the pressure and muzzle area at any

particular point, σ is the area of the tube, and X is the shot travel in the tube.

This paper presents a very elegant theory of recoilless weapons in concise form. It can be adapted easily for all practical purposes and calculations, using the particular weapon and powder characteristics of interest. J. Marinković, Yugoslavia

Soil Mechanics, Seepage

(See also Rev. 2521)

2698. **Low, A. J., The study of soil structure in the field and the laboratory,** *J. Soil Sci.* **5,** 1, 57–74, 4 plates, Jan. 1954.

After defining the sense in which the term soil structure is used in the paper, various methods for studying it are discussed, followed by a brief survey of recent literature. Descriptions are then given of adaptations of various methods which have been found suitable for studying structural changes in soils in long-term rotation experiments under the climatic conditions of Britain. As an indication of the usefulness of the methods, some results typical of those obtained in the field and laboratory are given.

From author's summary

2699. **Roscoe, K. H., An apparatus for the application of simple shear to soil samples,** *Proc. Third Inter. Conf. Soil Mech. Foundation Engng.*, Aug. 16–27, 1953, vol. I, 186–191.

Disadvantages of standard shear box are well known. In order to eliminate them, Kjellmann [AMR **4,** Rev. 4333] suggested an apparatus whose cylindrical form, however, generated a new source of inconvenience. Therefore, author invented a new shearing device to test rectangular soil samples applying uniform two-dimensional simple shear strain. Measurement of volume changes during shear is also provided for.

The apparatus is somewhat complicated; its principle is strain control. The sample box has hinged side walls; their lower inside edges are held in position by roller bearings mounted on swivel brackets. To overcome edge effects, a lubricated rubber sheet is stretched over the inner surface of side walls.

Photos of sliced plasticine samples are shown and compared with similar samples in the standard box, showing the achieved uniformity in shearing strain. Experimental results with real soils and comparison with other methods will be given in a subsequent paper.

Author develops a stress function which satisfies precisely the boundary conditions of the stressed state in the sample tested with above apparatus. This function is used to determine stresses and displacements. Apart from some discontinuities at the corners, results are convincing that the bulk of the sample is subjected to simple shear strain. Á. Kézdi, Hungary

2700. **Karpoff, K. P., Pavlovsky's theory for phreatic line and slope stability,** *Proc. Amer. Soc. civ. Engrs.* **80,** Separ. no. 386, 19 pp., Jan. 1954.

In the design of earth dams, levees, and other earth hydraulic structures, determination of the position of the theoretical line of saturation in the embankment and study of the slope stability are important factors. The following methods, involving only a few basic equations, will be useful to engineers in checking design assumptions such as: seepage loss, the point of intersection of the line of saturation with the downstream slope of an embankment, the steepness of the slopes, the stability of the slopes, and the necessity of improvement of the stability of slopes by the placement of a blanket of pervious material. For a given reservoir level, the seepage loss will become constant and the line of saturation will reach its highest position when complete saturation occurs. A field check of the ultimate position of the line of saturation, seepage loss, and the effect of the seepage pressure on stability of the slope can be made only after steady-state condition has taken place. From author's summary

2701. **Leonards, G. A., Strength characteristics of compacted clays,** *Proc. Amer. Soc. civ. Engrs.* **79,** Separ. no. 360, 45 pp., Dec. 1953.

Paper reports the basic factors, such as water content, void ratio, and degree of saturation, that influenced the shear strengths of two laboratory-compacted clays.

"Quick" triaxial shear tests were performed on specimens 1.42 in. in diam and 2.80 in. high. Test specimens were trimmed from a 10-in-diam compaction mold. Special techniques were employed which permitted the measurement of loads, weights, dimensions, and pressures to be made with a high degree of precision.

For the ranges in water content and degree of saturation used in these tests, it is shown that the strength of partially saturated clays is controlled by the void ratio at failure. This relationship is expressed by plotting the void ratio at failure to an arithmetic scale and the compressive strength to a logarithmic scale. Another important result was the greater strength values for specimens with the void ratio reduced through consolidation as compared with specimens compacted to the same void ratio and subjected to no consolidation before testing.

This study has added important relationships to the subject of compacted clay strengths. The techniques employed in assuring uniform specimens should be of material benefit to others planning similar laboratory studies. As pointed out by the author, there still remains much to be done on this subject. The influence of various types of compaction equipment, frost action, and moisture changes in field-compacted fills are factors yet to be evaluated. L. A. DuBose, USA

2702. **Tcheng, Y., A study of the stability of a mineral deposit on a thin layer of soft clay** (in French), *Proc. Third Inter. Conf. Soil Mech. Foundation Engng.*, Aug. 16–27, 1953, vol. II, 283–287.

Small-scale laboratory tests to determine the bearing capacity of a thin layer of soft clay overlying stiff marl are described in which grease was used as the soft material: first, with a rigid loading surface, and secondly, with a flexible surface with two different pressure distributions.

The experimental results are in fair accord with theoretical predictions based on a "$\phi = 0$" analysis.

R. E. Gibson, England

2703. **Bellier, J., Frey, J. P., and Marchand, R., Compressibility of the foundation rock under arch dams** (in French), *Proc. Third Inter. Conf. Soil Mech. Foundation Engng.*, Aug. 16–27, 1953, vol. I, 319–326.

By means of strain meters of the vibrating string type, the compression of the concrete of two arch dams and of the adjacent rock was measured. Though the measurements were not numerous, the results pointed out that the rock consisting of micaschist and granulite was, respectively, 5 to 13 times more compressible than the concrete of the dams.

F. C. de Nie, Holland

2704. **Engelund, F., On the laminar and turbulent flows of ground water through homogeneous sand,** *Trans. Dan. Acad. Tech. Sci.* no. 3; *Contr. Hydraulic Lab. Tech., Univ. of Denmark Bull.* no. 4, 105 pp., 1953.

Principal purpose of paper is to determine and evaluate sig-

nificance of head losses in immediate vicinity of wells resulting from resistance offered at casing perforations, particularly when turbulent flow occurs.

Author uses Lindquist's [First Congress of Large Dams, Stockholm] concepts: Hydraulic gradient proportional to discharge velocity in laminar range, proportional to velocity squared in purely turbulent range, and equal to $av + bv^2$ in range of partial turbulence. Considerable discussion is presented to justify this approach, including interesting comparisons of various relationships between resistance to flow and porosity.

Simple formulas are developed for "additional loss of head" (additional head required to maintain same discharge in cased as in uncased wells) for cylindrical, plane, hemispherical, and plane circular perforations in the well casing. Though approximations introduced result in minor reductions in accuracy, the simplifications achieved are significant. It is shown that the curvature of the casing has very small effect on head loss.

Analysis of turbulence shows its insignificance for uncased wells if the grain sizes are less than 1 mm; for cased wells, significant turbulence occurs even when grain sizes are as small as 0.3 mm, resulting in reduced discharge.

With special slotted permeameter, author obtains remarkable verification of his "working hypothesis." On this basis, a general, two-dimensional theory of turbulent flow is developed. The resultant vector equations are linearized by introduction of new variables—a procedure generally used in dynamics of compressible fluid flow; however, problems are solved only for complete turbulence. G. A. Leonards, USA

2705. Plain, G. J., and Morrison, H. L., Critical Reynolds number and flow permeability, *Amer. J. Phys.* **22,** 3, 143–146, Mar. 1954.

Flow permeability of porous medium is an important parameter in seepage phenomena. Numerous experiments have shown the Darcy law to be applicable only so long as the flow is laminar. Authors have determined permeability of fourteen media composed of nearly spherical glass beads, using a variable head permeameter. Darcy's law was found to apply up to Reynolds number of 75, with length and velocity parameters based on average grain diameter and interstitial velocity, respectively. Of particular interest are the three methods described for determining the average grain diameter and the close agreement obtained.
W. DeLapp, USA

Micromeritics

(See Revs. 2690, 2705)

Geophysics, Meteorology, Oceanography

2706. Dahler, H., Recent opinions on the weather-influencing effects in the troposphere and their prediction. Part I. Stating the problems. Labilization and stabilization by advection (in German), *Z. Meteor.* **8,** 1, 1–11, Jan. 1954.

2707. Van Dorn, W. G., Wind stress on an artificial pond, *J. mar. Res.* **12,** 3, 249–276, Dec. 1953.

The wind-induced slope of the surface in an 800-ft model-yacht pond has been measured to a relative accuracy of 5×10^{-7}. This slope is proportional to the sum of the surface and bottom stresses. The bottom stress was independently measured to an accuracy of 0.1 dynes cm^{-2} and was found to be negligible when compared to the surface stress. The surface slope is shown empirically to be the result of two effects: first, a tangential "friction" drag, which is invariably present and which is proportional to the square of the windspeed; and second, a "form" drag, which occurs only after the wind has increased above a certain value. The second effect is related to surface waves. Application of a detergent to the water eliminates both waves and form drag. The surface current was proportional to the wind speed and independent of waves. The slope increased with heavy rain, and a theoretical model is proposed which adequately predicts the observed increase.

The present study was modeled closely after Keulegan's experiments in a 60-ft laboratory channel [see AMR **4,** Rev. 3488]. The results of the two studies agree quantitatively.
From author's summary

2708. Reed, R. J., and Sanders, F., An investigation of the development of a mid-tropospheric frontal zone and its associated vorticity field, *J. Meteor.* **10,** 5, 338–349, Oct. 1953.

Authors study numerically the generation of vorticity at 500 mbs in a synoptic example of intense frontogenesis. At this level the primary factor in producing horizontal wind shear is the transformation of horizontal vorticity into vertical vorticity by horizontal variations of the vertical velocity. The horizontal temperature gradient also increases as a result of differences of vertical velocity; in this case the horizontal flow alone would have produced frontolysis.

Some uncertainty must exist regarding the representativeness of the case studied here, particularly as the authors find predominantly descending motion in the vicinity of the front.

An interesting suggestion made by the authors is that some air in the frontal zone has been derived from the stratosphere. The reviewer has also noted this phenomenon.
J. S. Sawyer, England

2709. MacCready, P. B., Jr., Atmospheric turbulence measurements and analysis, *J. Meteor.* **10,** 5, 325–337, Oct. 1953.

Satisfactory measuring techniques have been developed which overcome the four principal experimental problems arising in the investigation of atmospheric turbulence. (1) The data are made reproducible for statistical analysis by recording them on a portable magnetic tape recorder. (2) and (3) The problems of measuring wind-velocity fluctuations over broad ranges (frequencies between 0 and 50 cps, and magnitudes between 0.25 and 20 mps) are solved by using hot-wire anemometers together with nonlinear amplifiers. (4) Measurements at elevations up to several hundred meters are made feasible by the use of a multicable tethering system for a balloon which supports the measuring devices.

The techniques permit the measurement of velocity distributions, frequency spectra, autocorrelation coefficients, and heat flux at any elevation.

The difficulty of constructing such measuring and analysis equipment is balanced by the relative simplicity with which a complete statistical analysis of the data may be performed.
From author's summary

2710. Wippermann, F., Influence of the applied time interval upon the accuracy of numerical forecasting in nondivergent flow (in German), *Meteor. Rdsch.* **6,** 9/10, 180–182, Sept./Oct. 1953.

Using the model of harmonic wave solutions of the nonlinear vorticity equations given by Neamtan [*J. Meteor.* **3,** 53–56, 1946], the influence of the applied time interval upon the accuracy of numerical weather forecasting is discussed. It is shown that the correlation coefficient between the observable pressure field and the forecasted pressure field decreases with increasing applied time interval, and increases with decreasing phase velocity of the harmonic waves. H. Arakawa, Japan

2711. **Ogura, Y., Sekiguchi, Y., and Miyakoda, K., Classification of turbulent diffusions in the atmosphere,** *J. meteor. Soc. Japan* (2) **31,** 8, 1–16, Aug. 1953.

Modes of diffusion are classified and discussed according to the time of emission from the source, the mean flow of the fluid, and the spread about instantaneous or time-mean center of gravity. The theoretical discussion also includes the derivation of a relationship between the Eulerian and Lagrangian correlation coefficients. L. Machta, USA

2712. **Reed, R. J., Large-scale eddy flux as a mechanism for vertical transport of ozone,** *J. Meteor.* **10,** 4, 296–297, Aug. 1953.

Large-scale eddy flux proves to be of importance for the vertical transport of ozone and apparently assumes an equally significant role in the horizontal transport. From author's summary

2713. **Ogura, Y., Note on the theory of turbulent diffusion in the lower layer of the atmosphere,** *J. meteor. Soc. Japan* (2) **31,** 4, 125–131, Apr. 1953.

Statistical concepts have frequently been used in diffusion theories during the past few years, based mainly on the similarity laws of isotropic turbulence. Turbulence, however, is not isotropic in the atmosphere's surface layer. In this paper the nonhomogeneity is taken into account and it is shown how earlier results may be modified by introducing a correlation function which is dependent on height also. H. Merbt, Sweden

2714. **Yoshitake, M., On the dynamics of open systems and its application to the motion of typhoons,** *Geophys. Mag., Tokyo* 24, 4, 193–207, Mar. 1953.

By decomposing the equations of motion into a motion with respect to a moving frame of reference and a motion of this frame, author discusses different forces acting on a typhoon that govern the motion of the typhoon. It is shown that, besides the force due to change of Coriolis parameter with latitude, the influx of momentum into the region of the typhoon and skin friction also exert forces on the system. Computation shows that these forces are of the same order of magnitude. H.-L. Kuo, USA

2715. **Riehl, H., and Teweles, S., Jr., A further study on the relation between the jet stream and cyclone formation,** *Tellus* **5,** 1, 66–79, Feb. 1953.

An elongated area of increasing speed of the circumpolar jet stream moves across the United States. A wave cyclone forms on an existing cold front near the leading (or eastern) edge of this area of increasing winds. Margules' explanation of cyclogenesis cannot be true in this case because a cold dome rises rather than sinks. The wind maximum had a certain effect on vertical motion of the cold dome near its center and, if it had the same effect near the edges, cyclonic vorticity would be increased by the maximum wind in the region of cyclogenesis. J. C. Freeman, USA

2716. **Topping, A. D., On the elastic state of stress around a vertical cylindrical hole in a semi-infinite isotropic gravitational body,** Proc. First Midwestern Conf. Solid Mech., Engng. Exp. Sta., Univ. of Ill., 66–68, Apr. 1953.

The solution is found to be a simple one, with the stresses varying linearly with the depth. Author's treatment of the problem as a case of general axially symmetric stress is unnecessarily complicated. In the discussion following presentation of the paper, D. C. Drucker remarks that the problem is one of plane stress, retaining the linear terms which are frequently omitted [see Love, "Theory of elasticity," 4th ed., pp. 206–207].

R. D. Mindlin, USA

Lubrication; Bearings; Wear

2717. **Sines, G., The dynamics and lubrication of a miniature turbine rotor on porous bushings,** *Trans. ASME* **76,** 2, 319–326, Feb. 1954.

Author describes apparatus used to study dynamic behavior of a small shaft run in a porous bearing at very high angular velocities. A small air turbine on the shaft provides rotation and an optical system permits observation of the motion of the shaft in the clearance space. Depending upon conditions of angular velocity, rotor unbalance, and boundary lubrication, the shaft was found to operate in a fixed position, in a stable orbit, or in an erratic or random orbit. Possible mechanisms for the orbital or vibratory motions are considered. It is observed that the erratic orbital motion is accompanied by low friction and long bearing life.

C. D. Strang, Jr., USA

2718. **Thomson, A. S. T., Scott, A. W., and McBroom, H. L., Some factors in the design and lubrication of journal bearings,** *Trans. Instn. Engrs. Shipb. Scot.* **97,** part 4, 257–305, 1953–1954.

Results of experimental studies to determine effects of oil grooving, bearing materials, surface roughness, and the effect of "use" on oil are given for journal bearings.

E. F. Macks, USA

2719. **Drescher, H., Journal bearing with air lubrication** (in German) *ZVDI* **95,** 35, 1182–1190, Dec. 1953.

A report on mainly experimental research on both radial and axial bearings with air lubrication. The general result is that, with respect to Sommerfeld's similitude relation, no essential difference occurs between bearings with an air film and bearings with an oil film. The load on air bearings is limited by the small viscosity of air. On the other hand, air bearings permit high angular velocities of small rotors and have the advantage that the viscosity of air does not essentially depend on temperature. The bearings investigated generate a supporting air pressure distribution as a result of the rotation of a rotor to be supported. (The other type of bearing, fed by air under pressure through a system of jets, does not seem to have been considered.) For axial bearings, it is necessary to provide dips in the bearing surface so as to get fields of air stagnation supporting the rotor. Such fields are also useful for radial bearings, as they permit higher angular velocities without the effect of dynamic instability of the rotor.

Paper contains detailed descriptions of the bearings studied and also diagrams showing the essential results of the experiments.

H. Bückner, USA

2720. **Kiel, A., Should blocks or segments of synthetic material be used for journal bearings in rolling mills?** (in German), *Technik* **8,** 9, 609–612, Sept. 1953.

2721. **Vinograd, G. V., and Bezborod'ko, M. D., Viscous properties of plastic lubricants and rotation resistances of roller bearings** (in Russian), *Dokladi Akad. Nauk. SSSR (N.S.)* **90,** 6, 1019–1022, June 1953.

A series of experiments is described, during which several ball bearings and one roller bearing, 4-in. ID bore, were tested with varying amounts of grease ("Solidol," containing 17.5% Ca-soap and 2% water in a vegetable oil base). Open and sealed bearings were tested without any load application in order to better evaluate the frictional resistance produced by the lubricant. Torque vs. speed, torque vs. temperature, and torque vs. viscosity were recorded and are presented on graphs. Tests were also conducted with lithium-base grease with similar result. The temperature range was from 0 C to 50 C. L. M. Tichvinsky, USA

2722. Black, A. R., and Havely, T. W., Development and application of antiwear turbine oil, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-125, 6 pp.

Highly loaded reduction gears are being developed for marine use. Antiwear or mild extreme pressure lubricants are considered essential lubrication of these gears and for future progress in gear development. This paper shows that antiwear oils can be developed for reduction gearing without sacrifice in the other characteristics of today's high-quality steam-turbine oils.

From authors' summary

2723. Towle, A., and Vaile, P. E. B., Use of the Petter AV1 diesel engine for testing additive-treated oils, *J. Inst. Petrol.* **39,** 357, 581–622, Sept. 1953.

2724. Perry, R. J. S., The testing of I. C. engine lubricating oils by the Blogro engine under spark and compression ignition conditions, *J. Inst. Petrol.* **39,** 357, 632–637, Sept. 1953.

2725. Bell, C. O. R., The development of an inexpensive engine test for examining the bearing corrosion and detergency aspects of additive lubricating oils, *J. Inst. Petrol.* **39,** 357, 638–649, Sept. 1953.

Marine Engineering Problems

2726. Nordstrom, H. F., Full scale tests with the "Wrangel" and comparative model tests, *Medd. SkeppsProvAnst. Göteborg* no. 27, 92 pp., 1953.

Account is given of full-scale resistance tests conducted on the hull of the *Wrangel* (a discarded twin-screw destroyer of 228-ft length) and of corresponding experiments with models at $^1/_{10}$ and $^1/_{50}$ scale. The tests were carried out with and without appendages up to a ship speed of 20 knots. The hull surface of the ship was smoothed with composition and finished with two coats of paint. No reliable results were obtained in an attempt to measure the roughness of this hull surface. There is a quite satisfactory correlation between the full-scale and model tests. On three points on the bottom of the ship, friction plates were let in to the surface to measure local friction. By means of pitot tubes, the velocity distribution in the boundary layer was measured at two points and local friction coefficients were also calculated from these measurements. The results are evaluated on the basis of Nikuradse's sand-roughness conception. No reliable results were obtained by wake measurements. The recorded wave profiles on ship and model showed some differences, particularly in the bow wave region. Full details of the test arrangements are given, as well as tables of numerical data and a reference list.

L. Troost, USA

2727. Muckle, W., Approximate hydrostatic curves, *N. E. Cst. Instn. Engrs. Ship. Trans.* **70,** part 5, 329–342, Feb. 1954.

A simple method is given for determining data necessary for trim and initial stability calculations. Displacement and longitudinal center of buoyancy are first determined for several waterlines. From these, the tons per inch and the longitudinal center of flotation are derived and then, by making certain assumptions with regard to the waterlines, the transverse and longitudinal moments of inertia are obtained. Comparative calculations by this and a more exact method indicate probable errors of about 2%. The accuracy is sufficient for purposes of preliminary design.

M. St. Denis, USA

2728. Bukzin, E. A., Synthetic rubber protects the Navy's propeller shafts, ASME Ann. Meet., New York, Dec. 1953. Pap. 53—A-126, 7 pp.

2729. Mandel, P., Some hydrodynamic aspects of appendage design, *Soc. nav. Arch. mar. Engrs. Prepr.*, Ann. Meeting, Nov. 1953. Pap. no. 6, 33 pp.

This paper attempts to apply to appendage-design problems some of the more recent theoretical and experimental hydrodynamic data. In addition, design procedures are developed to permit rational selection of several of the geometric parameters of the various appendages. The appendages treated in detail are struts, rudders, and bilge keels.

The use of both bossings and struts on contemporary multiple-screw ships is explored. It is concluded that the use of either struts or bossings is determined by the contemplated operating conditions and mission of the ship in question. The important influence, determined theoretically, of nose radius on strut cavitation is shown. A new strut section shape is proposed which appears to reflect all of the various conflicting design considerations.

The various causes of rudder breakdown are categorized under the headings of stall, cavitation, and aeration. Powerful scale effects on stall angle and maximum lift are shown to exist even at quite high Reynolds numbers. These effects cast doubt on many existing experimental data on struts and rudders. The causes of severe rudder breakdown when it occurs in turning tests are examined, and it is concluded that, in most cases, the breakdown is attributable to stall. It is further concluded that evidence of rudder breakdown in model turning tests is in no sense indicative of full-scale breakdown.

Among the points developed in connection with rudder parameters are the following: (a) The all-movable rudder is distinctly the most favorable type of rudder, with the flapped and horn rudders following in that order. (b) Rudder angles in excess of 35° are often advantageous when all-movable rudders are used. (c) Increasing rudder aspect ratio, within the practical range, does not necessarily increase maximum lift. (d) A tabulation permitting the selection of rudder area for certain types of ships is shown. (e) An approach is suggested that, if successful, could replace Joessel's formula for predicting rudder torque. (f) The NACA (00 series) section shape is the most preferable of the conventional rudder section shapes. (g) Gap and horizontal break are important factors in reducing the effectiveness of the flapped and horn rudders, respectively, as compared to the all-movable rudder. (h) Short fast ships can benefit more from fast rudder deflection rates than large ships.

From author's summary

2730. Boykin, C. V., and Sellers, M. I., Practical problems relative to the use of aluminum alloys in ship construction, *Soc. nav. Arch. mar. Engrs. Prepr.*, Ann. Meeting, Nov. 1953. Pap. no. 3, 36 pp.

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